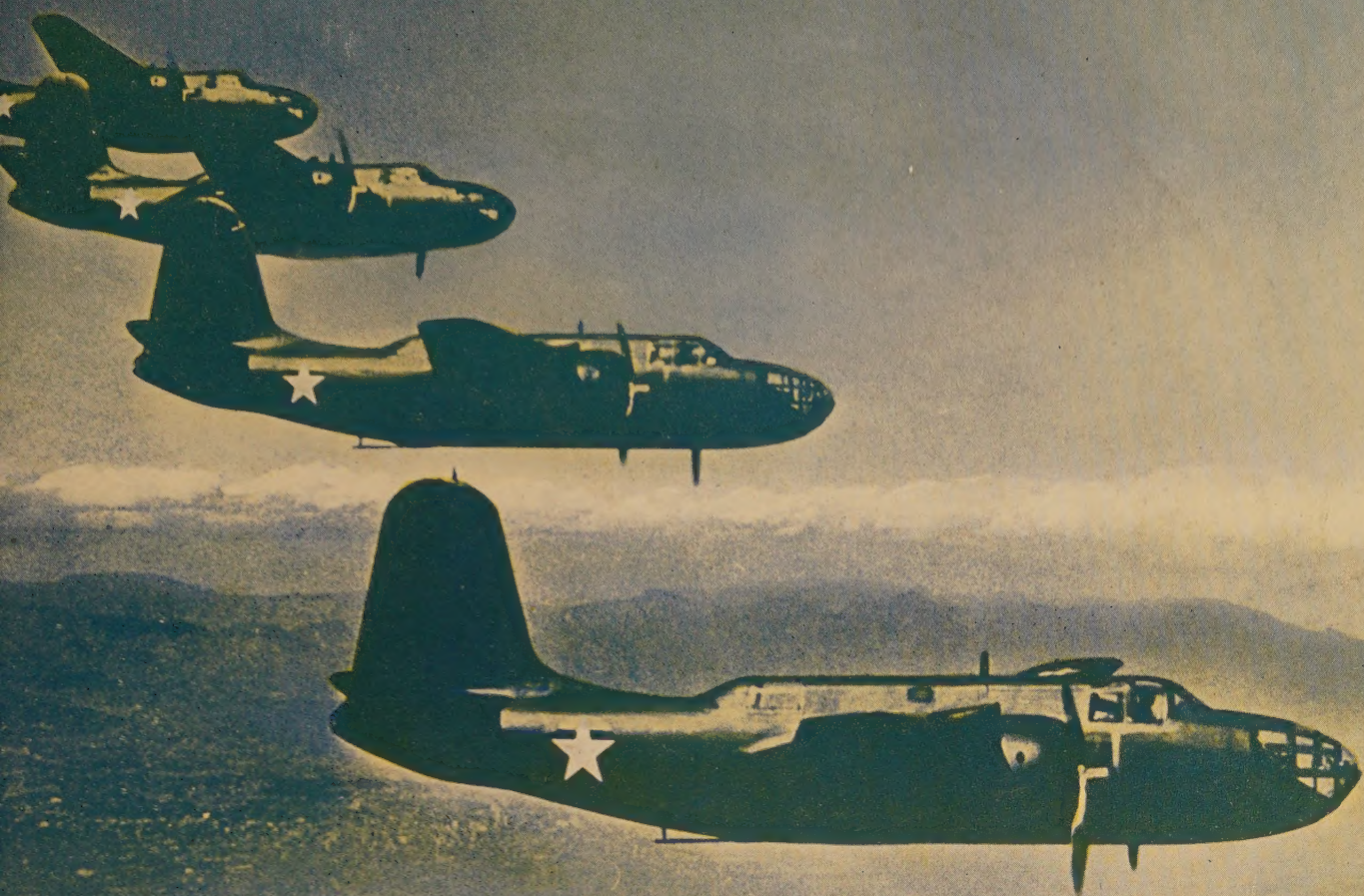


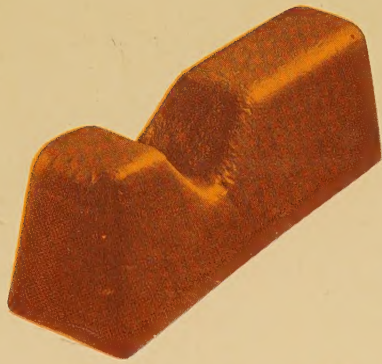


ELECTRICAL ENGINEERING

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Recent Developments in Organic Plastics for Electrical Insulation

THOMAS HAZEN

THE past decade has witnessed important developments in electrical insulating materials. Many are the result of the rapid and diversified growth of the organic-plastics industry.

It is the object of this paper not to catalog all the new plastics that may have interest as electrical insulating materials, but rather to review a few developments that have particular commercial importance. First the trend of these developments is covered briefly in a general way; then more specific data are given concerning the electrical properties and applications of certain new plastics. Among the materials given special notice are polystyrene, cambric varnishes, synthetic liquid dielectrics, and particularly the new wire and cable insulating compounds made from vinyl resins.

GENERAL TREND OF DEVELOPMENTS

In only a few instances is it possible to characterize a given material as a good or bad insulator. An electrical insulating material that may be ideal for one set of operating conditions may be useless where different conditions are encountered. This situation is mainly the result of two related causes.

In the first place, the variety of uses of electrical insulating materials has increased, from those uses involving only relatively simple d-c, power-frequency, and moderately high-frequency applications at only moderately high voltages and temperatures, to those at high voltages and ultrahigh frequencies. The new uses have created increasingly rigorous requirements with regard to mechanical and chemical stability under high temperatures, high humidities, exposure to oils and chemicals, as well as with regard to that ever important property of flammability. In the second place, the complex nature of the dielectric properties of the newer organic insulating materials complicates problems involving their use. In general, these electrical properties exhibit a marked dependence upon frequency and temperature because of the phenomenon known as dielectric absorption.

DIELECTRIC ABSORPTION

Dielectric absorption is characterized by the occurrence of peaks or maxima in the dielectric-loss factor versus frequency and the dielectric-loss factor versus temperature curves, always accompanied by compara-

The trend of recent developments in the field of plastics as electrical insulating materials and the electrical properties and applications of certain new plastics are discussed by a research physicist.

tively rapid changes in dielectric constant in the regions of these peaks.

In such a region of dielectric absorption, when temperature is the parameter, the dielectric constant shows

a more or less rapid decrease with increasing frequency as the dielectric-loss factor passes through a maximum. This type of dielectric behavior is illustrated clearly by the curves of Figure 1, which show the dielectric properties of an experimental compound as functions of the frequency at a fixed temperature. This Opalwax compound is a product obtained by the hydrogenation of castor oil. The curves are shown as an illustrative example only, since this type of material at present has a limited importance as a commercial dielectric.

Also, in a region of dielectric absorption, when frequency is the parameter, the dielectric constant increases more or less rapidly with increasing temperature as the dielectric-loss factor passes through a maximum. Figure 2 shows a typical manifestation of the phenomenon of dielectric absorption when the dielectric properties are determined as functions of temperature at a fixed frequency. Materials of the type of this rosin compound are among the oldest forms of viscous liquid insulation and are of considerable commercial importance.

In measurements of two experimental acrylic resins the dielectric properties were determined at room temperature over a range of frequencies extending from 60 cycles to 10 megacycles per second. The data obtained (Figure 3) indicated the occurrence of a broad maximum in the dielectric-loss factor versus frequency curve, but the frequency at which the maximum occurred was apparently much below the lowest frequency at which measurements were performed. There could be no doubt that the curves represented a true dielectric-absorption phenomenon, because the extremely high d-c resistivity (over 10^{15} ohm-centimeters) was much too high to contribute any ionic conduction losses to account for the relatively high power factors. From the nature of the dielectric-absorption phenomenon one could predict that, if the maximum dielectric loss occurred below the lowest frequency used in the measurements at room temperature, measurements performed at any of those frequencies should reveal dielectric power factor and di-

Thomas Hazen is physicist, research laboratories, Bakelite Corporation, Bloomfield, N. J.

electric-loss factor maxima at higher temperatures. A series of measurements performed on one of these resins at 60 cycles per second, covering a temperature range extending from room temperature to about 100 degrees centigrade, showed the maximum loss factor to be in the neighborhood of 55 degrees centigrade at this frequency (Figure 4).

The acrylic resins of Figures 3 and 4 have dielectric properties closely similar to those of the methyl methacrylate plastics. These materials have received considerable attention as electrical insulators and have a number of desirable properties, but their cost is relatively high. Incidentally, they are recommended quite often for use at high radio frequencies, but a dielectric-loss factor of 0.03 to 0.04 at ten megacycles per second is not exceptionally low as high-frequency insulators go, polystyrene, for example, having a loss factor of 0.0005 to 0.0007 at all frequencies, and low-loss steatite a loss factor of 0.0005 to 0.003 at ten megacycles per second.

Two types of mechanism are postulated to account for dielectric absorption. These are

1. Polarizations arising from the rotation of polar molecules or groups.
2. Polarizations caused by displacement of ionic charges.

The type of behavior displayed, however, is the same, regardless of the type of mechanism postulated to explain the absorption. The regions of dielectric absorption may be either broad or relatively narrow, depending upon the complexity of the structure of the material. Generally speaking, organic plastics tend to have extremely broad dielectric-absorption regions. Certain chemically simple resins and many liquid dielectric materials exhibit quite narrow dielectric-absorption regions, with sharp dielectric-loss-factor peaks and correspondingly abrupt changes in dielectric constant accompanying them.

During recent years various materials not necessarily new to the chemist have become new to the electrical industry in the sense that they have been made available in commercial quantities and have aroused a widespread interest among electrical research workers and engineers. While, with a few exceptions, these materials have been developed for mechanical uses, their potentialities as electrical insulating materials have been quickly recognized. With polystyrene, probably the most nearly perfect of all plastics from the purely electrical standpoint, only a small percentage of the annual output finds its way into electrical applications. It would appear, therefore, that large-scale production of plastics for mechanical uses has made available to the electrical engineer new types of insulation that might otherwise have been obtainable only at excessive cost. In many applications, of course, an electrical use of a material is also a mechanical use. In practice, certain highly desirable electrical properties frequently must be sacrificed so that necessary mechanical and chemical requirements, such as strength and rigidity, and heat, acid, alkali, and moisture resistance may be met. Conversely, it is sometimes imperative that mechanical or chemical properties be given secondary consideration in order that a material may be capable of fulfilling some particularly rigid electrical requirement.

THERMOSETTING PHENOLICS AND UREAS

The thermosetting phenol-formaldehyde and urea-formaldehyde resins, although among the oldest of all synthetic plastics, have undergone a number of improvements in recent years. One interesting development is transparent phenolic resins that can, with some reservations, be molded in the same molds used for filled compounds. Although thus far these resins have been used principally in mechanical applications, their electrical

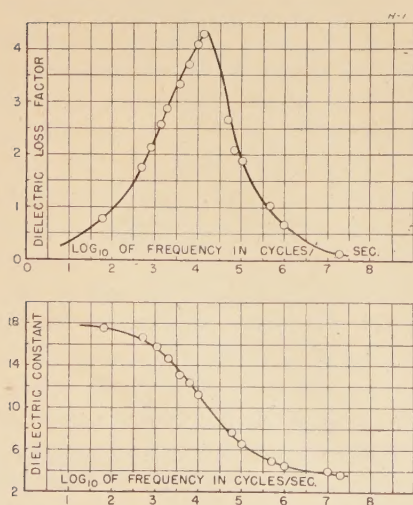


Figure 1. Dielectric properties of Opalwax compound as functions of frequency at 32 degrees centigrade

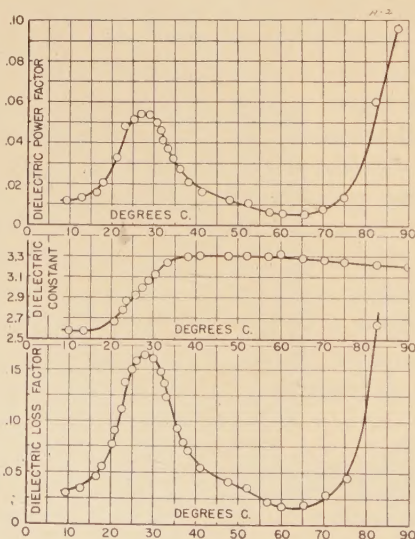


Figure 2. Dielectric properties of resin compound at 60 cycles per second

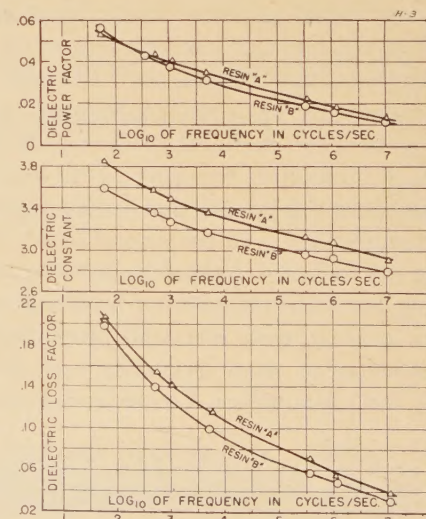


Figure 3. Effect of frequency on dielectric properties of acrylic resins at 26 degrees centigrade

properties make them worthwhile additions to the list of electrical insulating materials.

Some improvements in arc-resistant phenolic molding materials and in materials having good electrical and other properties at elevated temperatures have contributed considerably to the solution of difficult design problems in automotive ignition and related equipment. Surface arcing is troublesome with usual phenolic molding materials. Development of a modified phenolic molding compound with "nontracking" characteristics nearly equaling those of urea molding materials is a considerable accomplishment. Nevertheless, however "nontracking" a resin may be, such organic materials by their very nature have definite limitations where severe electrical arcing with its attendant high temperatures may be encountered. Organic material simply cannot compete with heat-resistant ceramic materials in such applications.

The effect of temperature on the electrical properties of phenolic molding materials has been studied closely for a number of years. However, it appears that designers of electrical equipment do not always allow for these temperature effects. This may be partly the result of the unfortunate custom among plastics manufacturers of stating values for various electrical properties at room temperatures only, without emphasizing the fact that these properties usually are af-

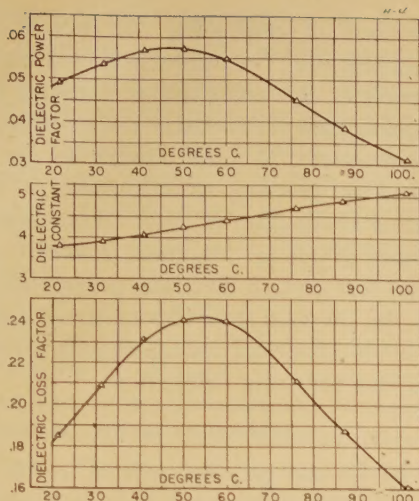


Figure 4. Effect of temperature on dielectric properties of acrylic resin A at 60 cycles per second

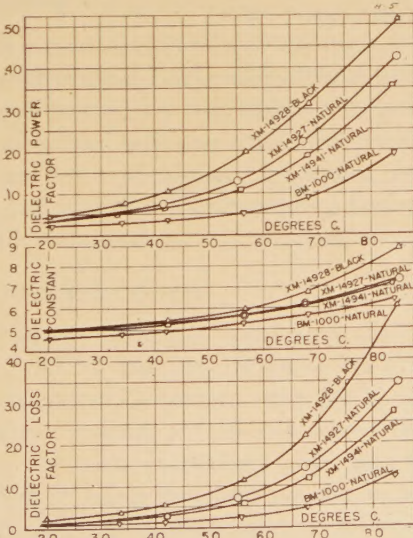


Figure 5. Effect of temperature on the dielectric properties of Bakelite molding materials at 60 cycles per second

These samples were all preheated 30 minutes at 220 degrees Fahrenheit

fected adversely by elevated temperatures. These adverse effects, however, should not be confused with the improvement in electrical properties that often may be brought about by after-baking molded pieces to expel moisture or to secure more complete cure of the bonding resins.

The curves of Figure 5 are typical illustrations of the effect of temperature on the power factor and dielectric constant of phenolic molding materials at 60 cycles per second. The effect of temperature on the d-c insulation resistance of typical phenolic molding compounds is shown by Figure 6, where the common logarithms of the measured values of insulation resistance between inserts molded into the materials are plotted against the temperature. Figure 6 shows that the insulation resistances of these typical phenolic-molded pieces are only about $1/1,000$ as high at 120 degrees centigrade as at 30 degrees centigrade. The beneficial effect of preheating, that is, of drying the molding material by warming just prior to molding, is also indicated by Figure 6. Generally speaking, both preheating and after-baking, when feasible, improve the electrical properties of phenolic molding materials.

Another important achievement of the past three or four years is the development of mineral-filled phenolic molding materials having low dielectric losses and molding characteristics permitting economical large-scale production of low-loss radio-tube bases. These materials have been welcomed by the radio industry to fill an urgent demand.

PHENOLIC-RESIN VARNISHES

New improvements in phenolic-resin varnishes for electrical insulation have been made in recent years. Special solutions for making varnished cambric have been

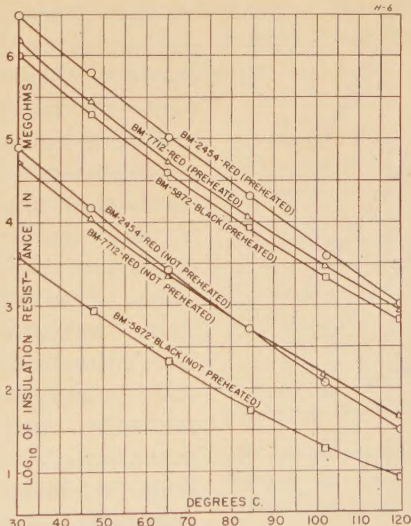


Figure 6. Effect of temperature on the insulation resistance of Bakelite molding materials

Specimen: two-inch disk with metal inserts

produced with electrical characteristics particularly advantageous from the standpoint of applications involving operation at elevated temperatures. Figure 7 shows the typical dielectric behavior of these varnishes at frequencies of 60 and 1,000 cycles per second as related to temperature. Cambrics made with these varnishes have a lower 60-cycle dielectric-loss fac-

tor at 80 degrees centigrade than at room temperature. This characteristic is obtained by taking advantage of the dielectric-absorption characteristics of these varnishes. This is done by control of the viscosity or cure of the finished film in such a way as to have the 60-cycle 80-degree centigrade operating conditions fall on the high-temperature side of the peak in the dielectric-loss factor-temperature curve. The success of these new cambric varnishes in practice depends partly on the selection of a good grade of cloth to obtain best electrical properties.

Phenolic-resin varnishes for laminated paper-punching stocks also have been improved considerably in recent years, despite the fact that the properties making for ease in cold punching appear to be incompatible with the good electrical and mechanical properties desired in the finished parts.

Cast phenolic resins have a connection with the electrical industry that is more mechanical than electrical, though some of these resins really possess excellent electrical properties in the highly cured state. Use of cast resins in radio cabinets and instrument cases represents primarily mechanical applications. An interesting use of electrical measurements, incidentally, has been made in connection with the

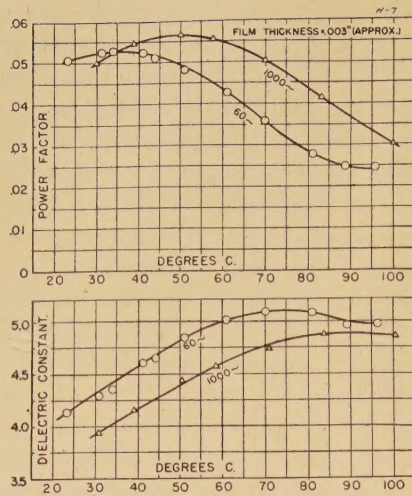


Figure 7. Effect of temperature on dielectric properties of phenolic-resin varnish film at 60 and 1,000 cycles per second

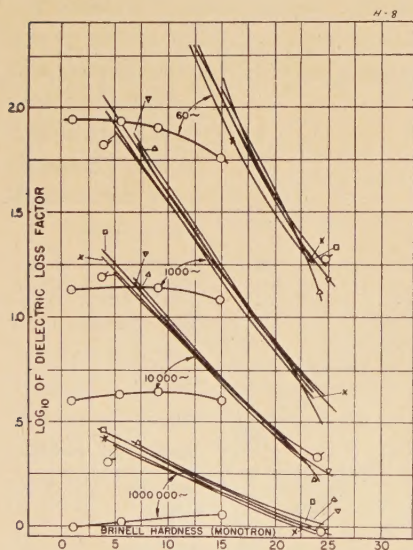


Figure 8. Relation of dielectric-loss factor at various frequencies, 25 degrees centigrade, to hardness of cast resins

- BT-48-306—transparent
- △—BT-45-005—translucent
- BT-45-107—red
- ▽—BT-45-345—blue
- ◇—BT-55-828-1—brown
- ×—BT-55-828-2—brown

problem of controlling the cure of cast resins during manufacture. A rather extended experimental investigation of the relationship between the hardness of a certain class of cast resins and its electrical properties has shown that it is quite feasible to use some convenient electrical property as a measure of the hardness, and hence of the state of cure. A summary of some of the results of this investigation is shown in Figure 8. The fact that certain electrical properties are closely related to the physical state of a material suggests a number of uses for electrical measurements other than for determining dielectric properties.

THERMOPLASTIC MATERIALS

By far the greatest activity in the plastics industry during recent years has been with thermoplastic resins.

This classification includes such well-known materials as cellulose acetate, cellulose nitrate, ethyl cellulose, methyl methacrylate, polystyrene, polyvinyl chloride, polyvinyl acetate, and copolymers of vinyl chloride and vinyl acetate. The rather mediocre electrical properties, particularly at radio frequencies, of

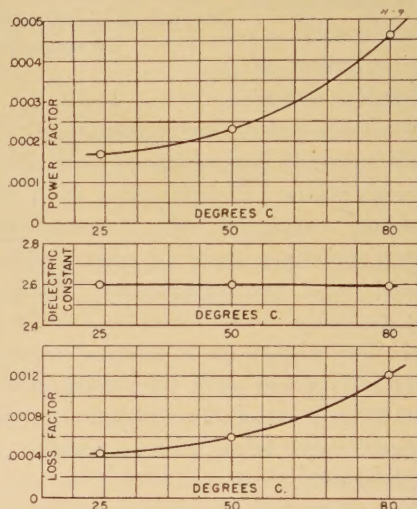


Figure 9. Dielectric properties of Bakelite polystyrene XMS-10,023 at 60 cycles per second

practically all these thermoplastics except polystyrene—together with certain limitations with respect to heat resistance, flammability, or mechanical rigidity—have tended to limit their use as electrical insulating materials. However, polystyrene and also the vinyl resins, because of their unusual combinations of properties, have become the two outstanding thermoplastics for electrical insulation.

POLYSTYRENE

The remarkable electrical properties of polystyrene have led to many new uses for this material. Perhaps one of the most interesting is that involving plasticized polystyrene film for the dielectric in tubular capacitors. Though this application may be regarded as barely out of the experimental stage, it appears to have considerable promise, because the capacitors have electrical characteristics equaling or surpassing those of the best mica capacitors for operation at moderate temperatures and voltages.

Because of the increasing demand for better and better insulating materials for use at ultrahigh radio frequencies,

polystyrene has assumed a new importance in the electrical industry, and there are numerous indications that its use will continue to show a rapid growth. Though long known for its exceptional electrical insulation properties, polystyrene had until comparatively recently been restricted in its applications because of its high cost of production. However, improvements in producing monomeric styrene on a commercial scale and advances in producing a polymer of high uniform quality have made possible much wider applications.

From the standpoint of electrical insulation properties alone, polystyrene has no serious rival among synthetic resins. It has high dielectric breakdown strength and extremely high d-c resistivity, even at temperatures near its softening point. Its extremely low power factor at all frequencies in the electrical spectrum rivals that of fused quartz, is better than that of many types of ceramic insulation, and is not greatly affected by temperature, as indicated by Figure 9. An interesting comparison of the electrical properties of polystyrene with those of a low-loss mica-filled phenolic molding material is shown by Figure 10. Being a nonpolar resin, polystyrene has a relatively low dielectric constant, and its dielectric properties have the highly desirable characteristic of being independent of frequency over an extremely wide range.

Use of polystyrene insulation in high-frequency equipment to replace certain inorganic insulators will be limited principally by its thermoplasticity, its relatively high coefficient of thermal expansion, its relatively low modulus of elasticity, and other characteristics common to organic materials in general. However, many of the objections to the use of polystyrene originally encountered can be minimized or eliminated entirely by close attention to design.

Polystyrene film as a capacitor dielectric, already mentioned, is only one of a wide variety of possible applications in the communications field. Polystyrene also has possibilities as a material for coil forms, stand-off

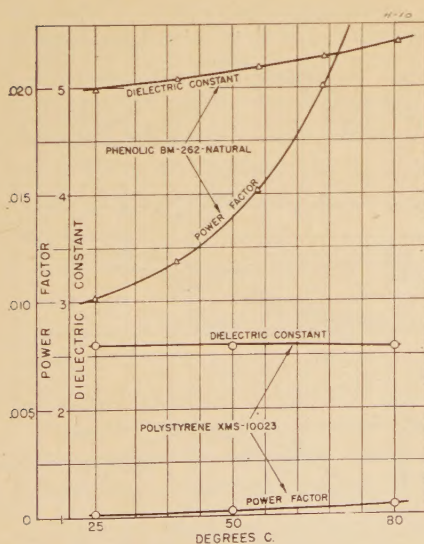
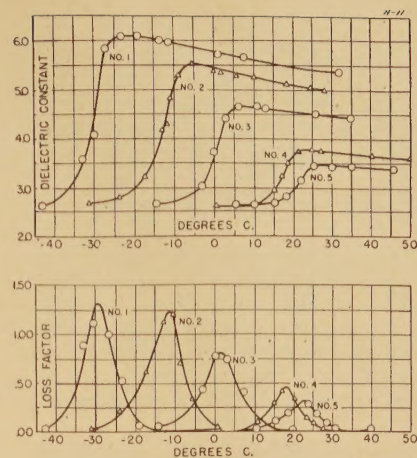


Figure 10. Dielectric properties versus temperature for Bakelite polystyrene XMS-10,023 and Bakelite phenolic BM-262 at 60 cycles per second

Figure 11. Dielectric properties of chlorinated diphenyl oxides at 60 cycles per second



insulators, insulating rods and bushings, coil-mounting strips, insulating beads for coaxial cable, and similar applications. Used as a lacquer or as

an ingredient in special compounds, it can be adapted to coating and treating coils, capacitors, and other circuit parts for resistance to moisture penetration.

Plasticized polystyrene for extruded wire covering has been tried on an experimental scale. While the excellent electrical properties of polystyrene were retained in good part, these coverings have comparatively low softening points and are somewhat lacking in toughness, resistance to cutting and abrasion, and flexibility at low temperatures.

Liquid polystyrene of low molecular weight has a number of interesting potential applications as a cable oil and capacitor dielectric.

LIQUID DIELECTRICS

The field of liquid insulating materials or liquid dielectrics is closely related to the plastics industry. Numerous resinlike or resin-containing liquids have been adapted for use as capacitor liquids, transformer oils, cable impregnants, and wire saturants. To the greatest extent possible in these applications the aim has been to combine the best obtainable electrical characteristics with the desired physical and chemical properties, such as viscosity, non-flammability, and resistance to sludge formation.

The dielectric properties of the chlorinated diphenyls are frequently cited as examples of dielectric absorption. The commercial chlorinated diphenyls form a series of compounds of varying chlorine content and varying physical state

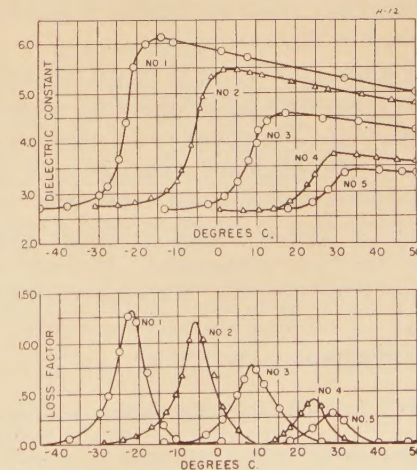


Figure 12. Dielectric properties of chlorinated diphenyl oxides at 10^3 cycles per second

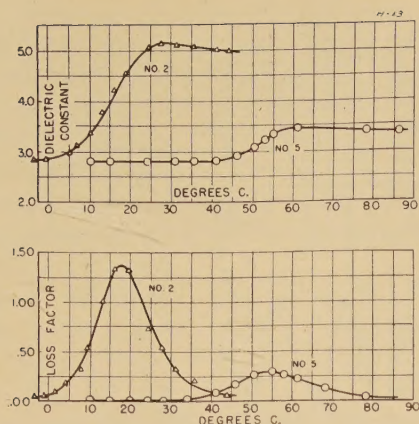


Figure 13. Dielectric properties of chlorinated diphenyl oxides at 10^6 cycles per second

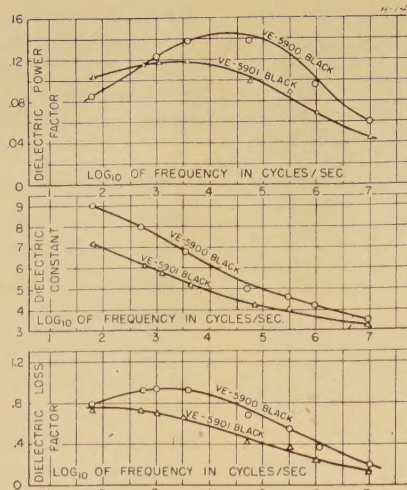


Figure 14. Dielectric properties of Vinylite extrusion compounds VE-5,900 black and VE-5,901 black at 27 degrees centigrade

Four-inch disk specimens

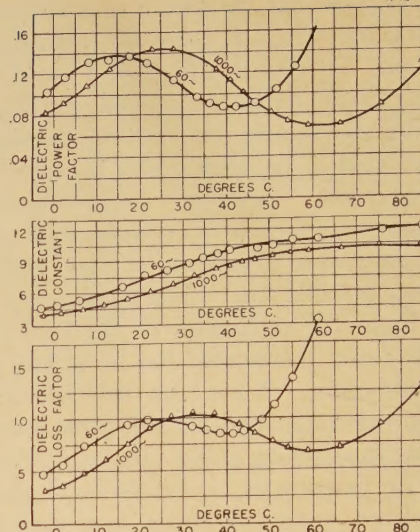


Figure 15. Dielectric properties of Vinylite-resin compound VE-5,900 black

at room temperature and thus furnish a group of compounds particularly suitable for study of the relationships between dielectric properties and physical and chemical structure.

A series of compounds having similar electrical and physical properties is represented by the chlorinated diphenyl oxides. Figures 11, 12, and 13 show the dielectric properties of some of these materials as functions of temperature at frequencies of 60, 1,000, and 1,000,000 cycles per second. The physical state of these materials at room temperature ranges from a thin liquid for sample 1 to a glasslike solid for sample 5. According to data supplied by the manufacturer, the chlorine content varied progressively from four substituted chlorine atoms per molecule in sample 1 to eight substituted chlorine atoms per molecule in sample 5. These materials all have relatively narrow dielectric-absorption regions. This dielectric absorption in the chlorinated diphenyls and chlorinated diphenyl oxides is generally regarded as caused by dipole rotation.

Figures 11, 12, and 13 reveal some of the complexities that arise when polar liquids are utilized as commercial dielectrics. The choice of a material suitable for a given application obviously must be made on the basis of a full knowledge of the dielectric behavior of the material itself, as well as all the probable operating conditions that may be encountered. It seems that in many instances the electrical properties required of a synthetic polar liquid dielectric come in conflict with the desired physical properties.

WIRE INSULATING COMPOUNDS FROM VINYL RESINS

The flexibility, toughness, oil resistance, water resistance, resistance to oxidation, and other desirable properties of the plasticized vinyl resins have led to their use as extrusion compounds for wire coverings, cable insula-

tion, and insulating tapes. In spite of some less desirable electrical properties, they have definite advantages over older types of wire and cable insulating materials. These vinyl-resin compounds promise to become the most important commercially of all the synthetic plastics used by the electrical industry.

Polyvinyl chloride plasticized with tricresyl phosphate is one of the more commonly used types of these new synthetic wire compounds. It has found a number of important uses, especially in applications where oil, moisture, and flame resistance are required. It is sold under such trade names as Flamenol and Koroseal.

More recent developments in this field have resulted from new copolymer resins prepared from vinyl chloride and vinyl acetate. These resins are particularly suitable for use in wire compounds. Vinylite resin compounds VE-5,900 and VE-5,901 are representative of commercially available products of this type. These

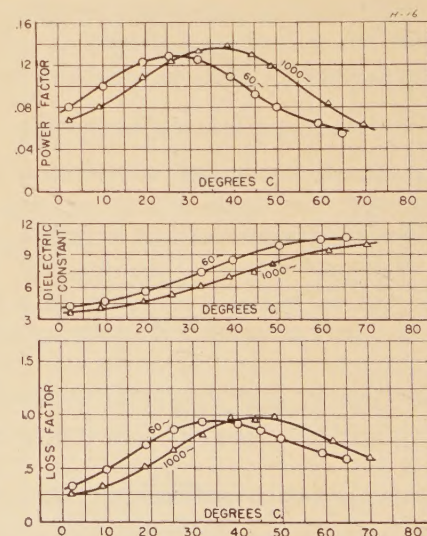


Figure 16. Dielectric properties of Vinylite-resin compound VE-5,901 black

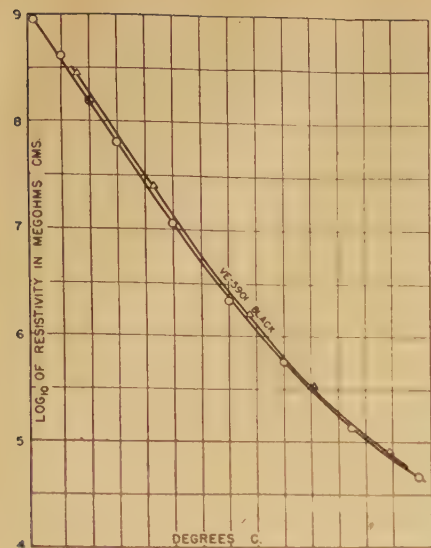
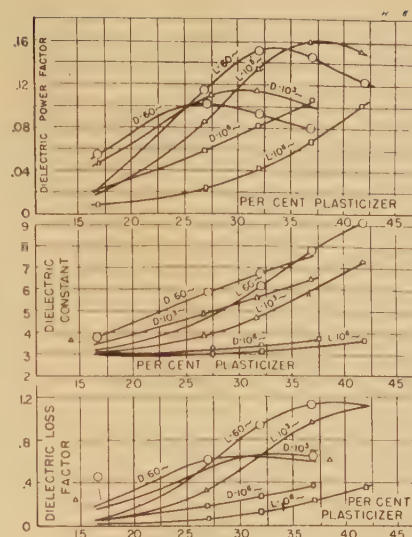


Figure 17 (left). D-c resistivity-temperature characteristics of Vinylite-resin compound VE-5,901 black

Samples
 ○ 30-foot length
 △ 60-foot length
 Compound extruded on number 14 solid wire

Figure 18 (right). Variation of dielectric properties with plasticizer content for Vinylite-resin—tricresyl phosphate and Vinylite-resin—dioctyl phthalate compounds at 60, 10³, and 10⁶ cycles per second

25 degrees centigrade
 Four-inch disk specimens
 L—tricresyl phosphate
 D—dioctyl phthalate



compounds are produced in natural, black, and a variety of bright colors.

The electrical properties of the plasticized vinyl-resin compounds are rather complex. Figure 14 shows characteristic curves for the flexible Vinylite resin VE-5,900 and for the somewhat stiffer VE-5,901 compounds. The power factor, dielectric constant, and dielectric-loss factor at room temperature are shown as functions of frequency over the range between 60 cycles and 10 megacycles per second. The curves show broad dielectric-absorption maxima and the accompanying decrease of dielectric constant with increasing frequency.

Figures 15 and 16 show the effect of temperature on the dielectric properties of typical runs of vinyl-copolymer compounds at frequencies of 60 and 1,000 cycles per second. The dielectric-power-factor and loss-factor maxima occur at lower temperatures for the VE-5,900 material than for the stiffer VE-5,901 compound. These measurements were made on wires insulated with the compounds in question, using the familiar water-immersion method. The somewhat poorer d-c resistivity characteristics of VE-5,900 are reflected in the more rapid increase in the ionic conduction losses at the higher temperatures than is evident with the VE-5,901 material.

Characteristic d-c resistivity-temperature curves for a sample of Vinylite wire insulating resin compound are shown in Figure 17. The effect of temperature is seen to be extremely marked, the ratio of the resistivity at 20 degrees centigrade to that at 85 degrees centigrade being approximately 10,000 to 1.

The most serious weaknesses of all the new types of plasticized vinyl-resin wire insulating compounds are those relating to the pronounced influence of both temperature and frequency on their electrical properties. Some of the more objectionable electrical characteristics, such as the high dielectric constant at low frequencies, may be improved by future research on these problems. Indeed, the whole development of these synthetics must be regarded as still in an elementary stage. However,

any major improvements will have to be of a fundamental kind, for the characteristic dielectric properties of these compounds are molecular in origin. Better plasticizers must be found, and perhaps modifications in the resins themselves will have to be made before any substantial improvement in the inherent electrical properties can be realized.

The effect of kind and amount of plasticizer on the physical and electrical properties of plasticized vinyl resins has been given a great deal of study. Figure 18 gives a summary of a rather extended set of electrical measurements on a Vinylite copolymer resin plasticized with various percentages of two of the commonly used plasticizers, tricresyl phosphate and dioctyl phthalate. These data show that the kind of plasticizer, as well as the amount, has a marked influence on the physical and dielectric characteristics of the finished compound.

The synthetic plasticized vinyl-resin wire compounds at present available are doing an excellent job in numerous applications, but the indications are that so far this trend toward the use of synthetic plastics in the insulation of wire and cables has only begun.

REFERENCES

1. The Dielectric Properties of Insulating Materials, E. J. Murphy, S. O. Morgan. *Bell System Technical Journal*, volume 16, number 4, October 1937; volume 17, number 4, October 1938; volume 18, number 3, July 1939.
2. Polar Molecules (book), P. Debye. Chemical Catalog Company, 1929.
3. The Dielectric Constant and Dielectric Loss of Plastics as Related to Their Composition, W. A. Yager. *Electrochemical Society Transactions*, volume 74, 1939.
4. Molecular Relaxation and the Elastic and Dielectric Properties of Plastics, L. Hartshorn, N. J. L. Megson, E. Rushton. *Physical Society Proceedings* volume 52, November 1940.
5. The Dielectric Characteristics of a Chemically Pure Synthetic Resin, C. G. Garton. *Institution of Electrical Engineers Journal*, volume 85, number 515, November 1939.
6. Plastics and Electrical Insulation, L. Hartshorn, N. J. L. Megson, E. Rushton. *Institution of Electrical Engineers Journal*, volume 83, number 502, October 1938.
7. Some Recent Advances in Industrial Plastics, W. G. Wearmouth. *Journal of Scientific Instruments*, volume 19, number 9, September 1942.
8. Dielectric Properties of Organic Compounds, S. O. Morgan, W. A. Yager. *Industrial and Engineering Chemistry* (industrial edition), volume 32, number 11, November 1, 1940.
9. The Dielectric Properties of Chlorinated Diphenyls, A. H. White, S. O. Morgan. *Franklin Institute Journal*, volume 216, number 5, November 1933.

A Comparison of the Transform and Classical Methods

WALDO V. LYON
FELLOW AIEE

THERE are two distinct steps in computing transient currents. The first is to derive a characteristic equation whose roots determine the character of the transient current. (This step is the same for all methods of computation.) The second is to compute the magnitudes of the transient currents. The only substantial difference between the transform method and the classical method is the way in which this computation is done. For comparing the amount of computation by the two methods three typical circuits are chosen. In the first, there are two transient terms. In both the second, which is more favorable, and the third, which is less favorable to the transform method, there are four transient terms. In each of these circuits it is assumed that the constants are adjusted so that the transient currents are both oscillatory (complex roots) and nonoscillatory (real roots). In addition, it is assumed that the circuits are at rest and also that there are initial currents and potentials. Thus, in all, 24 different cases are considered. In each case, it is assumed that the characteristic equation has been derived, that its roots have been determined, and also that the initial currents and potentials are known. The computation to obtain these necessary preliminary data is not included in the compilation, since this computation is the same in both methods.

The expressions for the transient current are derived by the transform and the classical methods, and the amount of computation required in each expression is determined. In this way more than 4,500 single operations of multiplication and addition are counted. Table I is a classified summary of the results of this counting. For example, with direct electromotive forces applied to the circuits, 852 multiplications and additions are necessary to compute the transient currents in all 12 cases by the transform method and 818 multiplications and addi-

This article compares the amount of arithmetical computation required to determine transient currents by the transform method with that required to determine the same currents by the classical method. The amount of arithmetical computation is measured by the number of times it is necessary to multiply or add two numbers. Comparison is made only for the case in which the circuits have few branches with lumped constants of resistance, inductance, and capacitance, and any advantage or disadvantage either method may have in other cases is not considered. No account is taken of the added effort necessary to acquire a working knowledge of the transform method nor of the time required to derive the transform expressions for the currents from the differential equations.

tions by the classical method. In 5 of these 12 cases the transform method requires less computation, while in 7 cases the classical method requires less. Of the 24 cases considered the classical method requires less computation in 17 cases, while the transform method requires less in 7 cases. The total number of multiplications and additions in all 24 cases is 1,833 for the classical method and 2,074 for the transform method.

In the eight cases involving second-order equations there is nearly 90 per cent more computation, and in

the 16 cases involving fourth-order equations 5.5 per cent more computation by the transform method than by the classical method.

SIMPLEST METHODS OFTEN ARE BEST

For determining the behavior of an electric circuit numerically one should use the simplest methods available, since both time and effort required to make the computation are reduced then to a minimum.

The simplicity of a method of computation is measured in terms of:

1. The effort required to master the necessary mathematical background.
2. The number of arithmetical operations required to perform the numerical computation.

When a circuit is analyzed by a method depending upon elementary mathematics, the physical characteristics of the circuit are understood more easily. This is so important for beginners that assumptions are made and details are ignored in order that a simple mathematical analysis may be made. As the circuit conditions become more complex, it is often better and sometimes necessary to use more advanced mathematical methods. These methods should be used with discretion however, since they may possess little or no advantage when applied to simple circuits. Just because a method of computation is based on more advanced mathematical

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knowledge is not a sufficient reason for using it in preference to a method based on less advanced mathematical knowledge. It should first be shown that numerical results can be obtained more directly and with fewer arithmetical operations by the more advanced method.

The gist of the argument for simplicity is this: Let us sharpen all our tools, particularly the simple ones, learn to use them skillfully, and choose the tool best suited to the task in hand.

TRANSIENT-CURRENT ANALYSIS

Much has been said in favor of operational¹ and transform^{2,3} methods of determining transient currents in linear circuits, so that the classical⁴ method of solution often is regarded lightly as lacking in power, unsystematic, and

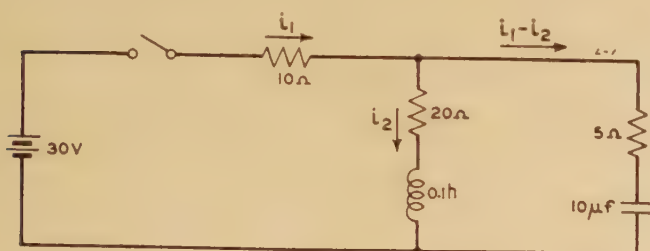


Figure 1

clumsy. It is fitting, therefore, that the classical method should have its case presented for the reader to decide whether or not this judgment of its effectiveness is warranted.

The case for the classical method is presented here only for the common-type problem in which steady electromotive forces, either direct or alternating, are impressed on a linear circuit consisting of a small number of branches with lumped constants. The current then consists of two components, a steady-state component and a transient component which disappears exponentially.

The steady-state component can be determined by the ordinary methods used in computing direct and alternating currents. There is no arithmetical advantage in computing it as a part of the operational or transform solution.

The transient component usually consists of a number of exponential terms of the form Ie^{pt} . There may be as many of these terms as there are units of inductance and capacitance in the circuit. The coefficient p in the exponent pt is either a real negative number or a complex number. Likewise, the initial magnitude I is either a real or a complex number. There are two steps in the solution for the transient current:

1. The coefficients p_1, p_2, p_3 , and so forth are determined.
2. The initial magnitudes I_1, I_2, I_3 , and so forth are computed.

The coefficients $p_1, p_2, \dots$, called the characteristic values are the roots of the same algebraic equation, called the

characteristic or determinantal equation, whether the classical method or the operational or transform method is used. It is fair to say that no advantage is gained in deriving this equation by one method or the other. The initial magnitudes I_1, I_2 , and so forth are computed differently by the two methods. The difference in the method of computing the initial magnitudes of the transient currents is the only substantial difference between the classical method and the operational or transform method.

CLASSICAL METHOD

In the classical method the initial values of the transient terms are determined by solving a set of simultaneous equations. There are several ways in which this can be done. A commonly used method is described by L. F. Woodruff.⁵ The illustrative circuit is reproduced in Figure 2. If the proper equations are solved by using a systematic process of elimination, a relatively simple formula is obtained for the initial value of each term of the transient current. The derivation of this formula depends only on well-known algebraic principles. The procedure is illustrated for a case in which there are four transient terms so that the expression for the instantaneous current i is:

$$i = i_s + I_1 e^{p_1 t} + I_2 e^{p_2 t} + I_3 e^{p_3 t} + I_4 e^{p_4 t} \quad (1)$$

where i_s is the ordinary steady-state current determined by the applied electromotive forces and the circuit constants. This expression for the current assumes that the characteristic values p_1, p_2, p_3, p_4 are all different. In the

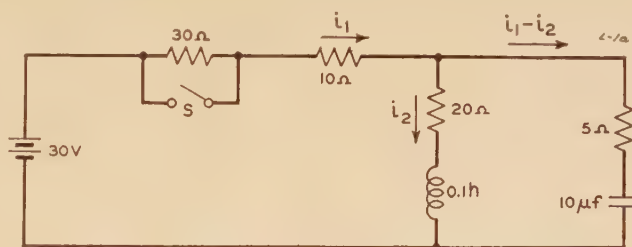


Figure 1a

following equations it is convenient to indicate first-, second-, and third-order derivatives by primes ($'$), double primes ($''$), and triple primes ($'''$).

At $t=0$

$$I_1 + I_2 + I_3 + I_4 = (i - i_s)_{t=0} = A \quad (2)$$

Differentiate equation 1 and obtain at $t=0$

$$p_1 I_1 + p_2 I_2 + p_3 I_3 + p_4 I_4 = (i' - i_s')_{t=0} = B \quad (3)$$

Differentiate equation 1 a second time and obtain at $t=0$

$$p_1^2 I_1 + p_2^2 I_2 + p_3^2 I_3 + p_4^2 I_4 = (i'' - i_s'')_{t=0} = C \quad (4)$$

Differentiate equation 1 a third time and obtain at $t=0$

$$p_1^3 I_1 + p_2^3 I_2 + p_3^3 I_3 + p_4^3 I_4 = (i''' - i_s''')_{t=0} = D \quad (5)$$

The initial values of i and its derivatives are obtained readily from the Kirchhoff differential equations relating to the circuit and the initial conditions imposed on the current in each inductance and the potential of each capacitance. The information obtained by evaluating the derivatives of the current is useful, since it shows how the circuit behaves initially.

If constant direct electromotive forces are applied to the circuit, all the derivatives of i_s are zero.

If steady sinusoidal electromotive forces are applied to the circuit, $i_s = I_s \sin(\omega t + \alpha)$, and its value and the values of its successive derivatives at $t=0$ are:

$$I_s \sin \alpha, \omega I_s \cos \alpha, -\omega^2 I_s \sin \alpha, -\omega^3 I_s \cos \alpha \dots$$

Reduce these four equations 2, 3, 4, 5, to three equations by eliminating I_4 systematically in the following manner. Multiply the first equation by p_4 and subtract from the second. Multiply the second equation by p_4 , and subtract from the third. Again, multiply the third equation by p_4 , and subtract from the fourth.

Reduce the resulting three equations to two by eliminating I_3 in a similar manner, this time multiplying by p_3 .

Finally eliminate I_2 from the remaining two equations and obtain the value of I_1 which is

$$I_1 = \frac{D - C(p_4 + p_3 + p_2) + B(p_4 p_3 + p_4 p_2 + p_3 p_2) - A p_4 p_3 p_2}{(p_1 - p_2)(p_1 - p_3)(p_1 - p_4)} \quad (6)$$

Note that p_1, p_2, p_3, p_4 are the roots, all different, of the characteristic equation which applies to the circuit. This characteristic equation is:

$$p^4 + ap^3 + bp^2 + cp + d = 0 \quad (7)$$

In such an algebraic equation the coefficient a is the negative of the sum of the roots, the coefficient b is the sum of the products of the roots taken two at a time, the coefficient c is the negative of the sum of the products of the roots taken three at a time, and the coefficient d is the product of all of the roots.

Because of these relations, it is seen readily that the expression for I_1 is more conveniently written

$$I_1 = \frac{D + C(p_1 + a) + B(p_1^2 + ap_1 + b) + A(p_1^3 + ap_1^2 + bp_1 + c)}{(p_1 - p_2)(p_1 - p_3)(p_1 - p_4)} \quad (8)$$

Note the systematic arrangement and composition of the terms in this expression. The coefficient of B is p_1 times the coefficient of C plus b . The coefficient of A is p_1 times the coefficient of B plus c . Also note that the last term is conveniently written as $A(-d/p_1)$, where d is the constant term in the characteristic equation. It requires eight additions and eight multiplications to

evaluate this value of I_1 numerically. The values of the other initial transient terms are found by advancing the subscripts in the customary manner. It is convenient to use equation 2 to check the computation of the transient terms.

The solution of equations 2, 3, 4, 5 for I_1 can be expressed as the ratio of two determinants, but this condensed form of solution entirely lacks the systematic simplicity of equation 8.

When the differential equation applying to the circuit is of the second order

$$I_1 = \frac{B + (p_1 + a)A}{p_1 - p_2}$$

or

$$I_1 = \frac{B - p_2 A}{p_1 - p_2} \quad (9)$$

This expression requires two additions and two multiplications to evaluate numerically.

SUMMARY OF CLASSICAL METHOD

The systematic procedure to be followed in the complete solution for the current in one of the branches of a linear network having lumped constants consists of five steps:

1. Write the Kirchhoff equations for the circuit in differential form. (This step is common to all methods.)
2. From the Kirchhoff equations, or otherwise, find the characteristic equation whose roots are the characteristic values $p_1, p_2, p_3, \dots$ (This step is common to all methods.)
3. Determine the steady-state value of the current in the usual way. (This step is a part of the transform solution.)
4. From the Kirchhoff equations and the given initial values of the current in each inductance and the potential of each capacitance determine the initial value of the current and the initial value of its first-, second-, third- . . . order derivatives. Also determine the steady-state current and its derivatives at $t=0$.
5. If the roots of the characteristic equation are all different,* compute the initial values $I_1, I_2, I_3 \dots$ of the transient currents by equation 8.

COMPUTATION OF THE INITIAL DERIVATIVES

The initial values of the first-, second-, and third-order derivatives of the current are computed from the Kirchhoff differential equations applying to the circuit. For example, the equations applying to the circuit of Figure 3 are

$$r_1 i_1 + L_1 i_1' = R(i_2 + i_3 - i_1) \quad (10)$$

$$E = r_1 i_1 + L_1 i_1' + r_2 i_2 + L_2 i_2' + \frac{q_2}{C_2} \quad (11)$$

$$E = r_1 i_1 + L_1 i_1' + r_3 i_3 + L_3 i_3' \quad (12)$$

* If some of the roots of the characteristic equation are equal, there are terms in the transient current of the form $I t e^{pt}$, $I t^2 e^{pt}$, and so forth. For example, if the differential equation applying to the circuit is of the second order, the transient current is $(B - pA)t e^{pt} + A e^{pt}$ where A and B are defined in equations 2 and 3. The case of equal roots is a special case of not great interest. The values of the transient terms are obtained readily by the same process that is used in deriving equation 8.

Table I

	Transform Method	Classical Method
D-c electromotive force applied.....	852.....(5).....	818.....(7)
A-c electromotive force applied.....	1,222.....(2).....	1,015.....(10)
Real roots.....	828.....(5).....	818.....(7)
Complex roots.....	1,246.....(2).....	1,015.....(10)
Initial conditions = 0.....	794.....(6).....	827.....(6)
Initial conditions $\neq 0$	1,280.....(1).....	1,006.....(11)
All conditions.....	2,074.....(7).....	1,833.....(17)

Note that these equations are not written in the Maxwell loop form but are written for branch currents with the unknown currents, i_1 , i_2 , i_3 , assigned to branches containing inductance. Solve these equations for $L_1 i_1'$, $L_2 i_2'$ and $L_3 i_3'$ in terms of the currents (in the inductances L_1 , L_2 , L_3) and the capacitance potential (q_2/C_2)

$$L_1 i_1' = R(i_2 + i_3 - i_1) - r_1 i_1 \quad (13)$$

$$L_2 i_2' = E - R(i_2 + i_3 - i_1) - r_2 i_2 - \frac{q_2}{C_2} \quad (14)$$

$$L_3 i_3' = E - R(i_2 + i_3 - i_1) - r_3 i_3 \quad (15)$$

For any given initial conditions, the initial values of the

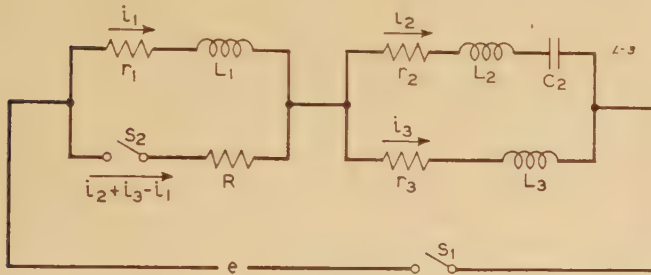


Figure 3

currents and capacitance potential appearing on the right of the equality signs are known. Therefore, the initial values of the first derivatives, i_1' , i_2' , i_3' , are determined.

Differentiate equations 13, 14, and 15 by adding a prime to each current, charge, and applied electromotive force. If a d-c electromotive force is applied, $E' = 0$. The differentiation gives

$$L_1 i_1'' = R(i_2' + i_3' - i_1') - r_1 i_1' \quad (16)$$

$$L_2 i_2'' = 0 - R(i_2' + i_3' - i_1') - r_2 i_2' - \frac{i_2}{C_2} \quad (17)$$

$$L_3 i_3'' = 0 - R(i_2' + i_3' - i_1') - r_3 i_3' \quad (18)$$

Substitution of the known values of the initial first derivatives, i_1' , i_2' , and i_3' , and the initial current i_2 , on the right of the equality signs determines the initial values of the second derivatives, i_1'' , i_2'' , i_3'' .

By continuing this process the initial values of the third derivatives are determined.

If a direct electromotive force is applied to this circuit when the initial currents and capacitance potential are

zero, it requires 15 multiplications and 10 additions to determine i_1' , i_1'' , and i_1''' .

COMPUTATION OF TRANSIENT CURRENT BY THE CLASSICAL METHOD

When the current is of the form Ie^{pt} , the fall in potential through a resistance of R ohms is RIe^{pt} ; through an inductance of L henrys, $LpIe^{pt}$, and through a capacitance of C farads, Ie^{pt}/Cp . The ratio of the fall in potential to the current sometimes is called the "generalized" impedance and is R for a resistance, Lp for an inductance, and $1/Cp$ for a capacitance. These generalized impedances can be combined in series or in parallel in exactly the same way resistances are treated in d-c circuits. For example, the generalized impedance, Z , at the terminals of the circuit of Figure 1 is

$$Z = 10 + \frac{(20 + 0.1p) \left(5 + \frac{1}{10^{-5}p} \right)}{20 + 0.1p + 5 + \frac{1}{10^{-5}p}}$$

The characteristic equation results from equating Z to zero, and is

$$1.5p^2 + 10,350p + 3 \times 10^6 = 0$$

or

$$p^2 + 6,900p + 2 \times 10^6 = 0$$

from which

$$p_1 = -6,600, p_2 = -303$$

Since the current i_1 , delivered to the circuit is desired, write the Kirchhoff differential equations as follows, substituting i_2' for di_2/dt :

$$30 = 10i_1 + 20i_2 + 0.1i_2' \quad (19)$$

Table II. D-C Electromotive Force Applied

		Transform Method			Classical Method		
		×	+	Total	×	+	Total
Figure 1, $i_1 = 0$ $q = 0$	Real* roots.....	15..	6..	21..10..	6..	16	
	Real† roots.....	11..	0..	17			
	Complex* roots.....	28..	11..	39..11..	4..	15	
	Complex† roots.....	18..	8..	26			
Figure 1a $\left\{ \begin{array}{l} i_1 \neq 0 \quad q \neq 0 \\ S \text{ closed at } t = 0 \end{array} \right\}$	Real* roots.....	24..	14..	38..10..	10..	20	
	Real† roots.....	20..	14..	34			
	Complex* roots.....	36..	17..	53..13..	8..	21	
	Complex† roots.....	29..	14..	43			
Figure 2 $\left\{ \begin{array}{l} i_1 = 0 \quad i_2 = 0 \\ q_1 = 0 \quad q_2 = 0 \end{array} \right\}$	Real roots.....	32..	21..	53..39..	34..	73	
	Complex roots.....	52..	25..	77..57..	36..	93	
	Real roots.....	55..	36..	91..53..	45..	98	
	Complex roots.....	83..	44..	127..75..	49..	124	
Figure 3 $\left\{ \begin{array}{l} S_2 \text{ closed} \\ S_1 \text{ closed at } t = 0 \\ i_1' \text{ and } q = 0 \end{array} \right\}$	Real roots.....	37..	22..	59..35..	30..	65	
	Real† roots.....	29..	22..	51			
	Complex roots.....	59..	30..	89..55..	32..	87	
	Complex† roots.....	51..	26..	77			
Figure 3, S_1 closed until steady state is reached. S_2 closed at $t = 0$, i_1' and $q \neq 0$							
Kirchhoff equations using branch currents. Equations solved by elimination	Real roots.....	65..	42..	107..47..	43..	90	
	Complex roots.....	99..	50..	149..69..	47..	116	
Maxwell's loop equations. Equations solved by determinants							
	Real roots.....	77..	48..	125			
	Complex roots.....	131..	68..	199			

* Equations in reference 2.

† Canceling p in numerator and denominator where possible.

$$30 = 15i_1 - 5i_2 + \frac{q}{10^{-6}} \quad (20)$$

The initial derivative of the current i_1 is computed more directly from these equations than from the Maxwell loop equations which frequently are not the best form of the Kirchhoff equations. At $t=0$

$$i_2 = 0, q = 0$$

From equation 20

$$i_1 = 2.0$$

From equation 19

$$i_2' = 100$$

Differentiate equation 20

$$0 = 15i_1' - 5i_2' + 10^6(i_1 - i_2) \quad (21)$$

At $t=0$

$$i_1' = \frac{-200,000 + 500}{15} = -13,300$$

The current i_1 , decreases initially at the rate of 13,300 amperes per second. The steady-state value of i_1 is 1.0 amperes

$$A = 2 - 1 = +1$$

$$B = -13,300 - 0$$

By equation 9

$$I_1 = \frac{-13,300 + 303(+1)}{-6,600 + 303} = 2.065$$

The corresponding computation by the transform method is

$$I_1 = \text{Res}_2 = \frac{[30][(0.1)(-6,600)^2 + (25)(-6,600) + 10^6]}{[-6,600][(3)(-6,600) + 10,350]} = 2.063$$

By equation 9

$$I_2 = \frac{-13,300 + 6,600(+1)}{-303 + 6,600} = -1.065$$

COMPARISON OF ARITHMETICAL COMPUTATION IN THE TRANSFORM METHOD WITH THAT IN THE CLASSICAL METHOD

This comparison relates only to the computation of the magnitudes of the transient currents. No account is taken of the added time and effort necessary to acquire a working knowledge of the transform method, nor of the time required to derive the transform expressions for the transient currents from the differential equations, such as equations 10, 11, and 12 applying to Figure 3. It is assumed that the initial value of the current in each inductance and the potential of each capacitance are known or have been computed, that the steady-state current has been computed, and that the characteristic equation has been derived and its roots determined. Although this preliminary computation may be from one half to two thirds of the entire computation in the complete solution for the current, it is not included in the

Table III. A-C Electromotive Force Applied

			Transform Method			Classical Method		
			×	+	Total	×	+	Total
Figure 1, $i_1 = 0$	$q = 0$	Real roots	21	10	31	14	8	22
		Complex roots	34	15	49	15	6	21
Figure 1a, $i_1 \neq 0$	$q \neq 0$	Real roots	30	18	48	14	12	26
		Complex roots	47	22	69	17	10	27
Figure 2	$\begin{cases} i_1 = 0 & i_2 = 0 \\ q_1 = 0 & q_2 = 0 \\ i_1 \neq 0 & i_2 \neq 0 \\ q_1 \neq 0 & q_2 \neq 0 \end{cases}$	Real roots	53	29	82	57	43	100
		Complex roots	89	43	132	79	47	126
		Real roots	73	44	117	63	51	114
		Complex roots	121	62	183	85	55	140
Figure 3	$\begin{cases} i_1 \text{'s and } q = 0 \\ i_1 \text{'s and } q \neq 0 \end{cases}$	Real roots	47	30	77	51	41	92
		Complex roots	82	40	122	71	46	117
		Real roots	77	43	120	55	47	102
		Complex roots	125	67	192	77	51	128

compilation since it is the same for both the transform method and the classical method. The three circuits in Figures 1, 2, and 3 are chosen for comparing the arithmetical work required to compute the magnitudes of the transient currents by the two methods.

There are two transient terms in Figure 1 and four transient terms in Figures 2 and 3. With each circuit, it is assumed first that the constants have values which give real roots, and then that they have values which give complex roots. The applied electromotive force is assumed first to be direct and then to be alternating. Thus, in all, 24 different cases are studied. In each case the expression for the magnitude of the transient current is derived by the transform method and also by the classical method (equation 8). Since the transform expression for the transient currents is derived from the differential equations applying to the particular circuit, the form of the expression depends both upon the configuration of the circuit and upon the way in which the expression is derived. The following transform expressions for the current in Figures 2 and 3 are used to determine the number of arithmetical operations when a direct electromotive force E is applied to the circuit. The subscript zero (0) indicates an initial value of current or potential. For Figure 2 (current i_1):

$$I_1 = \frac{(\lambda_1 p_1 + \sigma_1) \left(L_1 p_1^2 + r_1 p_1 + \frac{1}{C_1} \right) - M p_1^2 (\lambda_2 p_1 + \sigma_2)}{(L_1 L_2 - M^2) (p_1 - p_2) (p_1 - p_3) (p_1 - p_4)}$$

where

$$\lambda_1 = L_1 i_{10} + M i_{20}, \sigma_1 = E + V_{c10}$$

$$\lambda_2 = L_2 i_{20} + M i_{10}, \sigma_2 = V_{c20}$$

For Figure 3 (current i_1):

$$I_1 = \frac{R(r_3 + L_3 p_1)(E - V_{c0} + L_1 i_{10} p_1) + \left(L_2 p_1^2 + r_2 p_1 + \frac{1}{C_2} \right) \times \left[R \left(\frac{E}{p_1} + \lambda \right) + L_1 L_{10}(r_3 + L_3 p_1) \right]}{L_1 L_2 L_3 (p_1 - p_2) (p_1 - p_3) (p_1 - p_4)}$$

where

$$\lambda = L_1 i_{10} + L_3 i_{30}$$

Modified equation 8:

$$I_1 = \frac{D + C(p_1 + a) + B(p_1^2 + ap_1 + b) - A \frac{d}{p_1}}{(p_1 - p_2)(p_1 - p_3)(p_1 - p_4)}$$

In each of these expressions a count is made of the number of times two numbers are multiplied and of the number of times two numbers are added. In the classical method the computation of the initial derivatives is included. The results of this counting are given in Tables II and III. For example, with a direct electromotive force applied in Figure 2 at a time when the initial currents and potentials are zero and the constants are adjusted, so that the roots are complex, 52 individual multiplica-

tions and 25 individual additions are required by the transform method to compute all of the transient terms. For this case, 57 multiplications and 36 additions are required by the classical method.

Table I is a summary of Tables II and III.

REFERENCES

1. Operational-Circuit Analysis, **V. Bush**. John Wiley and Sons, Inc., New York, N. Y., 1929.
2. Laplacian Transform Analysis of Circuits With Linear Lumped Parameters, **J. Millman**. *Electrical Engineering*, volume 61, April 1942, pages 197-205.
3. Transients in Linear Systems, **Murray F. Gardner and John L. Barnes**. John Wiley and Sons, Inc., New York, N. Y., 1943.
4. Differential Equations, **D. A. Murray**. Longmans, Green and Company, New York, N. Y., 1904.
5. Electric-Power Transmission (first edition), **L. F. Woodruff**. John Wiley and Sons, Inc., New York, N. Y., 1925. Page 234.

Fluorescent Lighting in Wartime Britain

R. O. ACKERLEY

WHATEVER part fluorescent lighting may have played in speeding Britain's war production, there can be no argument that the war has affected profoundly the development and exploitation of the fluorescent lamp. To appreciate how great the influence of war has been it is necessary to look back to the situation that existed before September 1939.

Prior to 1939 development of fluorescent lighting in Britain had been directed mainly towards high-voltage tubes, the majority of the installations being of a decorative or semidecorative nature. Nevertheless, the possibilities of this class of lighting for more practical and utilitarian purposes had not been overlooked entirely, and as far back as 1936 high-voltage fluorescent tubes were used to light the gauge room of one of Britain's new aircraft shadow* factories which were then just coming into existence. At that time the necessary color values for industrial work could not be obtained from a single tube, and so combinations of tubes of varying colors were used to give a suitably blended result.

These early installations, for a number of other gauge rooms were similarly equipped during the next two or three years, revealed all those qualities of fluorescent lighting

which are now so familiar—low brightness, soft shadows, low and even dissipation of heat, and a light color of great psychological value for operatives who had to work continuously in artificial light. By the beginning of 1939, tubes giving a white light, similar to that of the mains-voltage tubes in general use in Britain today, had replaced the combinations of blended colors, but they were still available only in the high-voltage form.

DEVELOPMENT PROGRAM ALTERED BY WAR

Encouraged by the early success of their counterparts in the United States, however, Britain was developing the mains-voltage tube steadily behind the scenes, and by summer of 1939 it was visualized that the first of these tubes would be on the British market before the end of the year.

Until that time it was believed that the main market for fluorescent lighting would be in the commercial- and decorative-lighting fields—shops and offices, restaurants and theaters, public build-

ings and the like—and for this purpose relatively short low-wattage tubes, would be appropriate. The possibility of the tubes being adopted widely for industrial lighting was thought to be quite a secondary consideration.

* A shadow factory is an already existing factory not in use for war-production purposes, which could be fitted for production in a comparatively short time if the necessity arose.

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Then came the outbreak of war. The whole program had to be reconsidered to meet altered circumstances. Engineers in Britain then were confronted with a situation where all new lighting in the decorative and commercial fields was likely to be stopped dead until further notice, and all effort had to be directed toward helping industry produce the sinews of war. It looked as though the introduction of the fluorescent lamp was likely to be postponed indefinitely. In fact, the first decision was to postpone all development of it, but circumstances of war changed this.

The circumstances which led to a reversal of policy were due to the very greatly increased use of artificial lighting in industry, caused partly by the enormous increase in night-shift working and partly by the introduction of black-out. Really light-tight and quickly removable black-out was not practicable in many cases, so that permanent black-out had to be installed, and work was carried on under artificial light night and day. Workpeople who never before had had to work for more than a few hours at a stretch under artificial light, and then always with the knowledge that it was only a temporary necessity, found themselves faced with the prospect of doing all their work under artificial light for an indefinite number of years.

80-WATT TUBE A RESULT OF WAR

In many cases, no doubt, the artificial lighting previously installed was not so good as it should have been. Whether this was so or not, and quite apart from any special visual qualities of fluorescent lighting, there seemed to be an obvious need for some sort of light which gave more nearly the psychological qualities of daylight. Fluorescent lighting seemed to fill the bill, but were the particular lamps already in stock right for this new purpose? It was thought not. It was considered that for industrial purposes something giving a greater volume of light per tube was wanted, in other words a higher wattage. On the other hand, the time was not ripe to start the design and production of new control gear. Designers, toolrooms, and development laboratories were all working at high pressure to meet the special demands of war.

Consequently, it was decided to try to make an efficient lamp that would work with a choke (ballast) already in production. The most suitable was that made for the 80-watt high-pressure mercury-vapor lamps, and so the 80-watt fluorescent tube was born early in 1940 as a direct child of the war. There is no doubt that its birth has been a blessing, but, before indicating those fields in which its use has been most beneficial, some points in connection with the lamp and its accompanying gear and fittings may be of interest.

The lamp, which is 5 feet long and $1\frac{1}{2}$ inches in diameter, has bayonet caps (another wartime expedient to take advantage of existing production) and is made in one color only. This is near daylight selected for suit-

ability in industry and closely similar to but rather warmer than the American daylight color. Surface brightness is not enough to incur the risk of reflected glare from the very many polished metals in use in war industry. Choke (ballast), starting switch, and a small radio-interference-suppressor capacitor are supplied, either as separate units or mounted together as a single assembly. In each case they are generally supplied ready wired into the reflector.

LAMP GEAR INTERCHANGEABLE

Power-factor correction is obtained by capacitors, either one for each lamp ($7\frac{1}{2}$ microfarads), in which case it is also usually accommodated in the fitting, or by means of larger capacitors for groups of lamps. Both glow and thermal switches are available, and each lamp manufacturer markets his own complete range of gear. All systems of gear, however, are designed to operate with all manufacturers' lamps.

Recently, a system of wiring has been introduced whereby 50 per cent of the fluorescent tubes in an installation are operated in an inductive circuit identical with that used previously, except that the power-factor capacitor is omitted. The other 50 per cent of the tubes are operated in capacitive circuits embodying a special capacitor in series with each choke, to control tube current. This arrangement gives unity power factor and in a large measure eliminates stroboscopic effect. It is not necessary for the two lamps of each pair to be in the same fitting, provided they are sufficiently close to ensure adequate overlap of light, if elimination of stroboscopic effect is desired.

As regards reflectors for use with the lamps, here again war conditions in Britain have imposed limitations. Anodized aluminum has had to be reserved for more vital uses, and, in general, reflectors are of sheet steel, white-enamelled. They are made in various types for one, two, or more lamps, mostly with light distributions similar to that from RLM (Reflector Lamp Manufacturers Association) reflectors with tungsten lamps. For certain purposes such as underground workshops cut out of solid rock, reflectors showing a proportion of upward light, through a slot cut immediately behind the lamps, have proved helpful. Where specular control of light is essential, as, for instance, to direct light on to maps and chart walls, mirror glass reflectors are employed.

What part then, has fluorescent lighting played in helping Britain's war effort, and where has it been employed most usefully? Right from the start it has been a question of using the tubes where they were likely to do the most good, rather than letting every would-be purchaser who took a fancy to them have as many as he wished. In the early days of the war this husbanding of resources was necessitated by the limitations of factory output. Demand exceeded supply, and it took some months to get production on an adequate scale.

AVAILABLE ONLY FOR PRIORITY WORK

More recently another factor has caused a careful check on the use of fluorescent lighting, namely, making the most of available materials so as to save shipping space for other purposes. It is recognized that under peace conditions fluorescent lighting would be, in general, better for most industrial purposes than those systems previously employed. Any extra cost would be recovered in improved quality and quantity of production and higher morale of workpeople; but in wartime it must be recognized that, to obtain a given output of light, the use of more materials in short supply than, for example, in tungsten lighting is involved. Consequently, it is necessary to consider whether in any particular instance the use of the older methods would result in any serious incapacity, and to use fluorescent light only where it can be relied on to contribute some definite advantage.

The qualities of fluorescent lighting which have been most beneficial are, in my opinion, the following, in order of importance:

1. The psychological quality, due to simulation of daylight, both in distribution and color. This assumes special importance because of the black-out which involves, in many cases, working day in and day out under artificial light. Even most night-shift workers, under ordinary conditions, can look forward to working in daylight every other month, but not so under the black-out. Undoubtedly, fluorescent lighting is conducive to a feeling of well-being and has a direct bearing on such problems as absenteeism and minor illness.
2. The quality of low brightness in particular relation to reflected glare. So large a proportion of wartime industries involves working on highly polished metals and other specularly reflecting surfaces and reading such things as micrometer gauges.
3. The daylight color value which enables many tasks previously reserved for daylight to be carried on under artificial light.
4. The general excellent visual quality of the light, achieved by its low brightness and large area source with resultant soft shadow. This quality justifies its use for specially fine tasks, such as fine assembly and accurate measurement.
5. Its qualities of heat dissipation, caused by the small amount of total heat dissipated in relation to light output (a corollary of its high luminous efficiency). Also the fact that only a relatively small proportion of this heat is radiant energy, liable to be re-directed by the reflector onto the worker, and that the heat is dissipated over a large surface area, thus eliminating risk of hot spots.
(All these factors also gain special importance in relation to the black-out, which brings ventilating and overheating problems as well as lighting problems in its train.)
6. High efficiency. While this quality is, of course, an important factor in all cases, it assumes special wartime importance in rela-

tion to the problem of improving the lighting in old badly lit factories. In many cases the wiring in these factories is old and out of date, and, even when this is not so, the special war effort has usually involved loading the mains with extra plant and machines. Consequently, any improvement in lighting is likely to involve at best new subcircuit wiring, at worst complete new mains if lamps of the same efficiency as before are to be used. In many cases, however, if fluorescent lamps replace tungsten, both quantity and quality of light may be improved greatly without disturbing existing wiring. High efficiency also, of course, means low fuel consumption, another important factor in wartime England.

7. Relatively small variation in light output with variation of voltage. This also has a special bearing on war conditions, as overloading of mains and the emergencies created by enemy action have in some cases made it impossible to maintain that constancy of voltage which was compulsory in peacetime. The drop in light output of fluorescent lamps for every one per cent drop in mains voltage is only about one third of that experienced with tungsten lamps.

Unfortunately, although war has created an opportunity for studying and improving industrial lighting, such as has never been known previously, it has not been possible to make any controlled or statistical analysis of the results. One of the reasons for this is that all factory-management personnel are far too occupied to be able to devote time to anything not of immediate importance nor likely to give immediate results. Another reason is that, even if someone could be found to watch results, it is impossible under the stress of war to control extraneous conditions. Changes and improvements in services, machinery, and personnel are constantly taking place as the exigencies of the situation demand, and it is not practicable to delay such changes in order to observe, over a sufficiently long period, the effect of altering one factor only.

Nevertheless, there is no doubt in the minds of those who have had experience with fluorescent lighting, whether as advisers, employers, or workers, that it is playing its part in getting on with the war. Today 99 per cent of five-foot lamps and fittings manufactured in Britain are employed in the war effort.

Fluorescent lighting in Ministry of Aircraft Production underground factory

The New York Times (from the London Times)



Ultrashort Electromagnetic Waves

III—Generation

I. E. MOUROMTSEFF
ASSOCIATE AIEE

The general theory behind electromagnetic waves is as old as Maxwell's field equations. The production of undamped ultrashort waves of any appreciable power, however, was delayed until the discovery and development of the magnetron as a high-frequency oscillator and the introduction of the type of velocity-modulation generator known as the klystron. The author of the accompanying article has not only designed and developed some of these new types of ultrashort-electromagnetic-wave generators but has contributed by his many interesting talks and technical papers to the advancement and general knowledge in this field. This is the third article of a series originally presented as lectures before the basic science group of the AIEE New York Section. The two preceding articles appeared in the March and April issues of "Electrical Engineering"

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IN his historical experiments, 1888, Heinrich Herz used electromagnetic oscillations of ultrahigh frequencies; they could also be termed microwaves. But from the very beginning the history of radio development showed a definite trend toward low frequencies or long waves, up to 12 miles in length. Only during the last 12 years, in response to the demands of television and frequency modulation have the ultrahigh frequencies become important. A brief review of the existing methods of ultrahigh-frequency generation is the topic of our discussion.

There are four main types of ultrahigh-frequency generators:

1. Conventional negative-grid generators.
2. Positive-grid or Barkhausen oscillators.
3. Magnetrons.
4. Velocity-modulation or electron-beam generators.

CONVENTIONAL NEGATIVE-GRID VACUUM-TUBE GENERATORS

A conventional generator of high-frequency oscillations consists of a vacuum tube and an external oscillat-

ing circuit composed of an induction coil L and a capacitance C connected between the anode and the grid of the tube (Figure 1). The load, no matter how it is physically coupled to the circuit, can always be conceived as a parallel resistance R_p . The generated frequency can be computed from William Thomson's formula:

$$f = 1/(2\pi\sqrt{LC}) \quad (1)$$

where L and C are measured in henrys and farads, respectively, or in any other consistent units. If we wish to increase the generated frequency, we have to reduce L and C or both. One will find that maximum power output from any tube is independent of frequency until a certain frequency level is reached, beyond which the output falls off very rapidly. There are three main factors limiting output and efficiency of a triode as frequency goes up:

1. Inductances and capacitances associated with tube electrodes.
2. Increased radio-frequency loss.
3. Finite electron-transit time.

The first two factors are of the nature of circuit limitations; the last one affects the electronic mechanism of the tube.

CAPACITANCES, INDUCTANCES, AND CIRCUIT LOSSES

One must realize that in a circuit as shown in Figure 1, the vacuum tube viewed as an a-c circuit element consists of capacitances C_{pg} , C_{pf} , and C_{gf} and inductances L_p , L_g , and L_f , inherent in the structural parts. The combined effect of capacitances on the generated frequency is equivalent to an increase of the tank capacitance, C , by the amount

$$C_t = C_{pg} + \frac{C_{pf}C_{gf}}{C_{pf} + C_{gf}} \quad (2)$$

At lower frequencies, when C is relatively large, as follows from equation 1, this effect is negligible. However, the higher the frequency, the smaller L and C , the more prominent becomes the role of the tube capacitances and inductances. In the extreme case C is zero, and tank inductance shrinks to a straight conductor short-circuiting the anode and grid terminals. The corresponding frequency, f_r , is called the *resonant frequency* of the tube.

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Practically no output can be generated at this frequency, but it may serve as an approximate figure of merit of the tube as an ultrahigh-frequency generator.

In order to understand better why power output should drop as the generated frequency approaches f_r , determined by the internal tube capacitance and inductance, we must turn our attention to an important property of every oscillating circuit, the dimensionless quantity, Q . It is the ratio of the energy stored in the circuit to the energy irredeemably converted per cycle into heat and electromagnetic radiation. Q is a measure of smoothness of oscillations (flywheel effect) and also of sharpness of resonance. In a well-designed circuit, when it is unloaded, Q must be as high as possible; with normal load in operation, Q is approximately 10

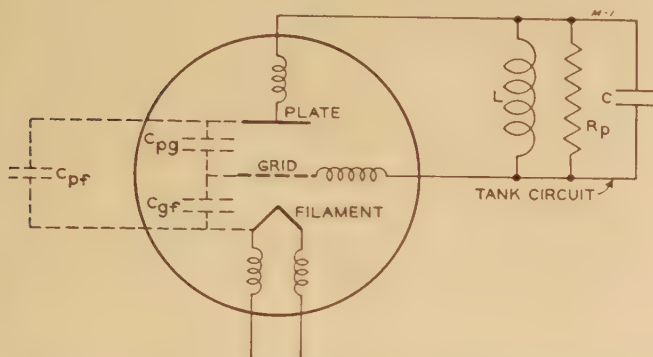


Figure 1. Negative-grid vacuum-tube oscillator with emphasized interelectrode capacitances and inductances

to 20. As function of circuit constants, Q can be expressed as

$$Q = R_p \sqrt{\frac{C}{L}} = R_p \omega C \quad (3)$$

hence

$$R_p = Q / \omega C \quad (4)$$

Here R_p is the parallel load resistance equivalent to the combined useful load and all kinds of circuit losses. For an efficient tube operation R_p must match the tube's internal characteristics, and, once operating voltages are chosen, there is not much leeway for variation of R_p demanded by the tube. However, as frequency goes up, the radio-frequency circuit losses increase, because of

1. The increasing skin effect.
2. Greater capacitance-charging currents.
3. Eddy-current loss in the adjacent conductors.
4. Dielectric loss in glass parts of the tube.
5. Energy loss by direct radiation from the circuit.

The latter loss becomes particularly prominent when the length of the generated waves becomes comparable with the circuit dimensions.

Thus, for any given R_p , the share of the wasted energy

in tube loading increases with increasing frequency at the expense of permissible useful load; hence, poor circuit efficiency and lower useful outputs. Moreover, a decreasing Q with increasing ω , while C is constant, results in a reduced R_p ; a low R_p affects proper matching of the tube; hence, poor efficiency of the tube itself. Also, if R_p , because of the losses, is low with the same radio-frequency voltage across it, the current through the load is higher; but the current through the load is equal to the electronic current through the tube, since purely reactive branches of the oscillating circuit do not load the tube. From tube charts it can be learned readily that, with an excessive demand for electronic current, tube operation becomes inefficient, if possible at all. Then, either a lower operating voltage must be chosen (hence reduced output), or the tube must be specially designed, with plenty of cathode emission and a higher perveance. But too much filament may become inconvenient from the structural viewpoint; also, it cuts down the permissible anode dissipation. A too high perveance generally means higher interelectrode capacitances.

Internal inductances, negligible at lower frequencies, may become troublesome in the region of ultrahigh frequencies. For example, a 40-mil wire four inches long has an inductance of approximately 0.1 microhenry. At an ordinary broadcast frequency of one megacycle per second, it represents an impedance of $0.1 \times 10^{-6} \times 2\pi \times 10^6 = 0.63$ ohm; at 100 megacycles per second it becomes 63 ohms, which will exercise considerable choking effect. In addition, the internal tube inductances may become an important limiting factor because of the difficulty of neutralizing the tube used as a power amplifier, as it is, for example, in television.³

From the previous discussion it follows that tubes intended for the generation of ultrahigh frequencies must be designed with low interelectrode capacitances and low connecting lead inductances and with higher than normal cathode emission. In addition, losses in associated circuits must be kept as low as possible; in other words, the circuits when not loaded must be of the highest possible Q .

The internal tube inductances can be kept down by making internal conductors of large diameter rods and of minimum length compatible with safe insulating distance between the anode and other tube terminals.

Low interelectrode capacitance can be realized either by reducing the electrode size or by spreading them farther apart from each other. The latter expedient, however, has its limits from the viewpoint of transit time, unless abnormally high operating voltages can be permitted. The reduction of the electrode's size implies that, the higher the intended frequency, the smaller must be the tube, the lower will be the heat-dissipation limit, the lower will be the maximum feasible power output. In a properly designed tube all unnecessary capacitances due to the structural portions of the electrodes are

eliminated or reduced to a minimum, leaving just enough length for the active or heated portion located opposite the cathode. Thus in ultrahigh-frequency tubes one may observe very short squat copper anodes, some with inverted or folded-up edges⁴ (Figure 2). In glass tubes, where all parts are located inside a glass envelope, the

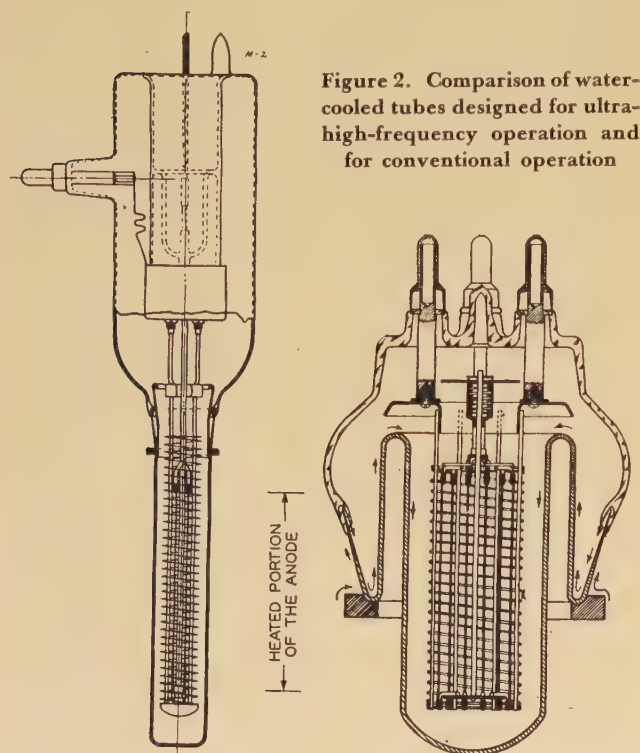


Figure 2. Comparison of water-cooled tubes designed for ultrahigh-frequency operation and for conventional operation

connecting leads, instead of being led through the conventional presses, are sealed directly through the envelope far apart from each other.

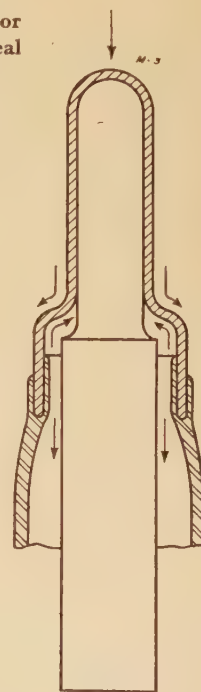
Because of high capacitance-charging currents (60 amperes is not an unusual value), careful consideration of the methods of sealing the leads through the glass is necessary; copper or Kovar thimbles are quite popular in high-output ultrahigh-frequency tube designs instead of ordinary presses (Figure 3). However, one must remember that the high-frequency currents do not follow the shortest paths between two conductors in direct contact with each other, as we would expect them to do, by transferring our knowledge from 60-cycle current technics. Because of the skin effect or limited depth of penetration of the electromagnetic field into conductors, discussed by Dr. Weber,¹ the ultrahigh-frequency current will follow the surface of the conductors meticulously, no matter how long and tortuous the path is. Therefore, in the case shown in Figure 3, the total current will flow around the feather edge of the thimble under the glass; this, in some cases, may cause troubles of cracked seals from excessive heating.

As mentioned before, the interest in ultrahigh-fre-

quency generators started about 12 years ago; first, purely academically; then, because of the demands of television and other modern applications. Large inter-electrode capacitance appeared to be the main obstacle in designing a large ultrahigh-frequency tube. Therefore, in one of the earliest high-power ultrahigh-frequency oscillators⁵ this difficulty was circumvented by using an l -meter-long portion of a concentric transmission line for the oscillating circuit, into which a tube was built as an integral part at its end; two tubes could also be used, as shown in Figure 4. The advantage gained by this design was a uniformly distributed capacitance and inductance of the transmission line. Dr. Ragazzini² showed that both depend only on the ratio of diameters of the outer and inner conductors and that the characteristic or surge impedance of the line is $Z_0 = \sqrt{L/C}$. Then, if the tube is also of a concentric design and has an equal Z_0 , an impulse given by the tube at the application of voltages travels unimpeded to the other end of the line l meters apart is reflected from it, travels back, is again reflected, and so on. As a result, a standing wave is built along the line with the voltage loops at the ends, and a current loop at the middle of the line. The generated wave length is $\lambda = 2l$. No limitation from the oscillating-circuit viewpoint is imposed either on tube length or on the value of its plate-to-grid capacitance, so long as this capacitance is the same per-unit length as it is for the rest of the line. Another advantage of using a concentric transmission line for an oscillator is its inherently high Q , that is, an inherently low circuit loss. However, in spite of its basic simplicity, such an oscillator is rather bulky and cannot be used as an amplifier, in view of a too close and uncontrollable coupling between the anode and grid circuits.

Much more flexible are oscillators constructed with parallel-rod or flat parallel-bar transmission lines. Here, the tubes must be so designed that their structural parts are an extension of the transmission line (Figure 5). The most convenient is to use two tubes in a push-pull scheme with separate transmission lines between the anodes, between the grids, and between the filaments. The tube capacitances are then lump capacitances in series with each other and together foreshortening the transmission line. A great number of ultrahigh-frequency oscillators are designed after this pattern.

Figure 3. Copper or Kovar thimble seal for heavy leads



From an operational viewpoint they are to be classified as tuned-plate tuned-grid oscillators. Feed-back or coupling in such an oscillator occurs through the plate-to-grid capacitance. The generated frequency is controlled by the length of the anode line and can be varied within certain limits. The grid and cathode lines permit one to control the amount of the feedback and to adjust the oscillator

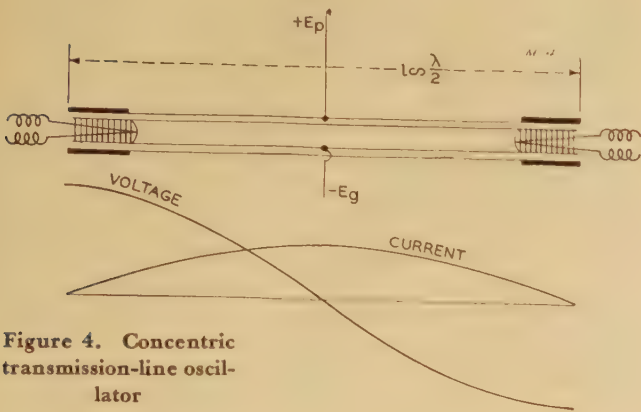


Figure 4. Concentric transmission-line oscillator

to an optimum power output. The length of the anode line, l , and frequency, $f = \omega/2\pi$, are connected by the relation

$$\frac{1}{\omega C_t} = Z_o \tan \frac{2\pi l}{\lambda} \tag{5}$$

where C_t is the composite tube capacitance foreshortening the line, and $Z_o = \sqrt{L/C}$ again is the characteristic impedance of the line, depending on wire spacing and diameter. The calculated length is always less than a

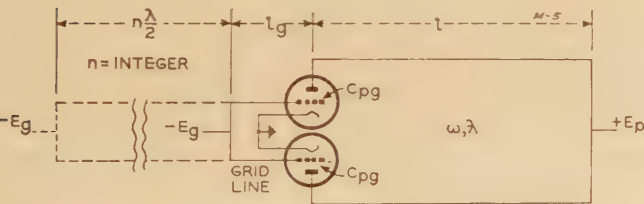


Figure 5. Parallel-rod transmission-line oscillator

$$\begin{aligned} \text{Usually } l_g < l \quad \frac{1}{C_{pg}\omega} &= Z_o \tan \frac{2\pi l}{\lambda} \\ l &< \frac{\lambda}{4} \\ C_t &= \frac{1}{2} C_{pg} \end{aligned}$$

quarter wave length, because only with $l < \lambda/4$ is the reactance of the transmission line inductive, which is necessary for establishing a resonance with the tube capacitance.

As shown in the drawing, the two tubes can be attached to the outer end of a quarter-wave-length trans-

mission line, or they can be located at the middle of a half-wave-length transmission line. The advantage gained by the latter arrangement is splitting of the foreshortening capacitances of the tubes between the two halves of the line and elimination of the open-end effect; therefore, somewhat higher frequencies can be realized.

If a tube is to be used as an ultrahigh-frequency power amplifier as in television, the oscillations caused by the feedback through the plate-grid capacitance, C_{pg} , are unwanted and would be called parasitic. They can, however, be avoided to a certain degree, either by conventional neutralizing of the tubes or by using screen-grid tubes. It was mentioned somewhere else that at higher frequencies neutralization becomes difficult because of the internal tube inductances. But, even with screen-grid tubes, a frequency level may finally be reached where parasitic oscillations would come through because of the unavoidable residual grid-plate capacitance.

TRANSIT TIME

Another important limitation in the negative-grid tube used for the generation of ultrahigh frequency is electron transit time. In low-frequency operation it is usually taken for granted that electrons leaving the cathode reach the anode instantaneously. Of course, nothing in nature happens instantaneously; but no harm is done by this assumption, so long as the actual time of flight of electrons between the cathode and the anode is negligible in relation to the duration of the cycle. For example, transit time of 1×10^{-9} second, which is not unusual, is only 1/1,000 cycle with $f =$ one megacycle per second. However, the same transit time becomes one tenth or a greater part of a cycle if the fre-

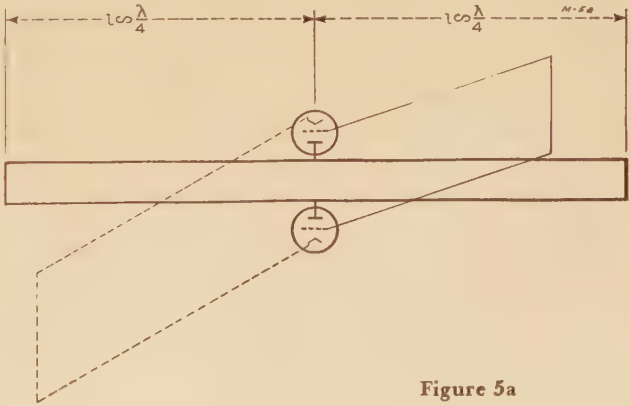


Figure 5a

quency is 100 megacycles per second or higher. The tube output approaches zero, as transit time becomes a certain fraction of the oscillating cycle. This fraction is given by various authors as between one half and one sixth.⁷

A rough idea as to why transit time should affect tube performance at all can be obtained by the following

reasoning: Power output of a vacuum-tube generator is equal to the product of two sine functions, radio-frequency anode voltage and the fundamental component of radio-frequency anode current. Let us assume, as is frequently the case in a normal operation, that they are 180 degrees out of phase. If we assume then, that transit time becomes Δt , the current begins to lag with respect to the voltage by an angle $\omega\Delta t$. Hence, the output must be multiplied by $\cos(\pi + \omega\Delta t)$, which is always less than unity.

In order to have a better picture of transit-time implications, we shall assume that a sinusoidal potential $E = E_0 \sin \omega t$ is applied between the grid and the cathode, and we shall follow the motion of individual electrons or groups of electrons leaving the cathode at different times. For simplicity's sake, we shall assume that the grid and the cathode are parallel planes separated by a distance, d_g , and also, that the electric field is homogeneous and equal to

$$D = D_0 \sin \omega t \quad (6)$$

We shall consider $D_0 = E_0/d_g$ constant throughout our investigation. The force applied to the electron is

$$F = eD_0 \sin \omega t \quad (7)$$

acceleration caused by it

$$a = \frac{eD_0}{m} \sin \omega t \quad (8)$$

and, if the electrons leave the cathode with zero velocity, the velocity at any time, t , is

$$v = \int_{t_0}^t a dt = \frac{eD_0}{m\omega} (\cos \omega t_0 - \cos \omega t) \quad (9)$$

Finally, the displacement at the time t is given by

$$S = \int_{t_0}^t v dt = \frac{eD_0}{m\omega^2} \{ \omega(t - t_0) \cos \omega t_0 + \sin \omega t_0 - \sin \omega t \} \quad (10)$$

Time t_0 is different for the individual groups of electrons and is indicative of the phase when they leave the filament. In Figure 6, curve 2, the parenthetic expression is plotted for several values of ωt_0 . The ordinates of the curves are proportional to the distance covered by the electrons during ωt after leaving the cathode, provided they do not encounter the grid before. Thus far, no assumption is made regarding the exact location of the grid.

From the displacement curves we conclude that:

1. The electrons leaving the filament during the first quarter of a cycle continuously drift away from the filament.
2. The electrons leaving the filament during the second half of the positive half-cycle return to the filament during the negative half-cycle. Whether this happens or not in actual tube operation is a matter of the actual location of the grid and of frequency as is implied by the factor $eD_0/m\omega^2$. A further examination of the displacement curves leads to other interesting conclusions (3, 4).

3. If the frequency is such that the first electrons reach the grid after the time interval $\omega t = \pi$, entrance of individual groups of electrons into the grid-plate space spreads over a much longer time interval than that which separates their departure from the filament. Thus, the time distribution of the plate current is of an entirely different shape from that of the original current in the vicinity of the filament; initially short current bursts become blurred and may even turn into a continuous flow of electrons between the grid and the plate, thus contributing nothing to power output.

4. The fact that many electrons may return to the filament indicates that, for the same average plate current, the filament must be capable of supplying higher instantaneous currents than in operation at lower frequencies.

Of course, in the preceding discussion of electron motion the effect of the space charge is not taken into consideration; it is also assumed that the oscillating field governing the electron flow from the filament is positive during one half-cycle and negative during the other half-cycle as in class-B operation. However, in class-C operation the field remains positive only during a part of the half-cycle; hence, the effect of the negative radio-frequency field on electron motion will be emphasized. The curves for the bias $E_1 = 1/2E_0$ are plotted

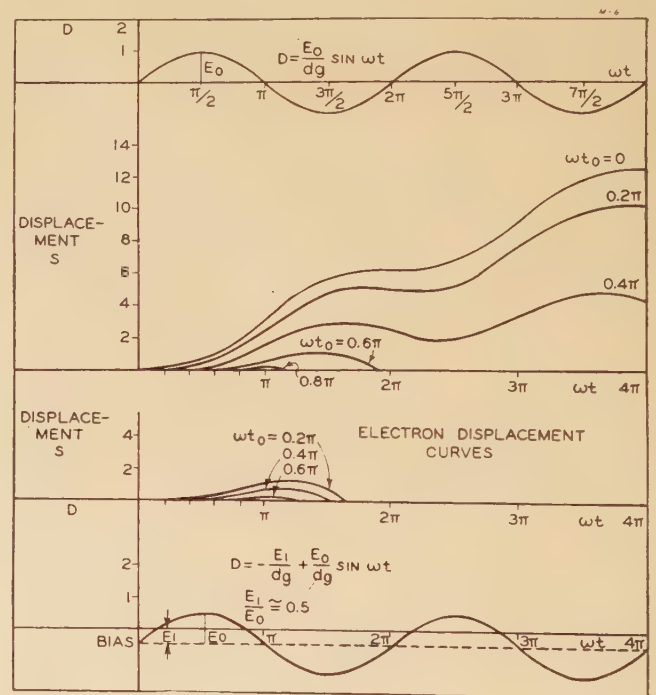


Figure 6. Electron displacement in a-c electric field

in the same Figure 6, curve 3. They again suggest that, depending on the actual location of the grid and on the frequency, some or even all electrons may return to the filament instead of reaching the grid. A more accurate mathematical treatment of the same problem can be found in a paper by Doctor Wang.⁸

Transit time also causes additional losses in a negative-grid triode operated at ultrahigh frequencies. Indeed,

in low-frequency operation no grid loss is to be reckoned with, so long as the grid remains negative. In ultrahigh-frequency operation, when oscillation cycle, T , approaches the total time of transit ($t_{af} + t_{pg}$), grid loss is incurred by moving electrons even in a negative grid.⁹ The reason for this is current resulting from the flow to and from the grid of positive charges induced on its surface by electrons moving toward or away from the grid. In low-frequency operation these currents caused by electrostatically induced charges are equal on both sides of the grid and flow in opposite direction; thus, their combined effect is nil.

This loss can be viewed as loss in an imaginary input conductance (real part of input admittance). This conductance rises rapidly with frequency and can be expressed by the relation

$$G_g = K S_m f^2 t_{gf}^2 \quad (11)$$

where K is a constant depending on structural and operational parameters of the tube, and S_m is tube transconductance. As frequency rises, G_g may become so high that the grid may virtually appear short-circuited to the cathode, thus preventing the proper tube excitation. This additional ultrahigh-frequency grid loss raises its temperature which in its turn may become another limitation.

POSITIVE-GRID OR BARKHAUSEN OSCILLATORS

Historically, this was the first ultrahigh-frequency vacuum-tube generator; it was discovered by Professor Barkhausen and his pupil Kurz¹⁰ in 1920. But, in spite of numerous papers and a great amount of experimental work since that time, the Barkhausen generator did not become too popular in practical radio applications, as its efficiency is extremely low, and its input is limited by grid temperature. Therefore, we shall touch upon it only briefly.

A Barkhausen oscillator can be made of practically every conventional tube by applying positive operating voltage to the grid and a negative potential to the plate. The electrons accelerated from the cathode reach the positive grid; some of them end their career right there by being intercepted by the grid. Some others fly through the grid meshes and find themselves in the decelerating plate-grid field. There they are stopped before reaching the anode and start on a return trip toward the grid; again, they are partly intercepted by

the grid and partly fly to the cathode. Here, they may land on the cathode or turn back again to start on another trip. This play repeats over and over again and, as observed by Barkhausen and Kurz, may give birth to oscillations of very high frequencies in a circuit connected between any two electrodes. Thus, some triodes with resonant frequency of 60 megacycles per second in a negative-grid circuit may produce oscillations of 300 megacycles per second and even more if used as Barkhausen generators utilizing these "electronic" oscillations.²⁰

The generated wave length λ , grid voltage E_g , and anode diameter d_a are generally connected by the relation:

$$\lambda^2 E_g = 10^6 d_a^3 \quad (12)$$

which shows that the generated frequency is controlled by the electronic mechanism of the tube, not by the external oscillating circuit.

THE MAGNETRON

Another type of ultrahigh-frequency generator is the magnetron. It was invented by Doctor Hull¹¹ in 1920 and originally was intended for low-frequency oscillations or to be used as an electron relay. Several years later it was discovered, first by Zacek¹² in Prague, and then by Professors Yagi¹³ and Okabe,¹⁴ that the magnetron may become an excellent device for generating microwaves. Essentially, a magnetron is a cylindrical diode with a magnetic field applied parallel to its axis. For the production of microwaves, the anode preferably is split by longitudinal cuts into two or more segments, ordinarily, but not necessarily, even in number. An output circuit is connected between the alternate segments. An important property of the magnetron, rendering it suitable for generating microwaves, is that transit time does not need to be shorter than the oscillating cycle; in fact, it may considerably exceed it. The theory of magnetron operation is rather complex, and exact mathematical analysis is difficult. It has been the subject of an enormous number of papers in the past, and a fairly complete discussion of all previous work is given in a German book by Otto Groos,¹⁵ "Introduction in Theory and Technics of Decimeter Waves," published in 1937. The basic conception of the electron motion within a magnetron was originally given by Doctor Hull¹¹ and more recently elaborated by Professor Brillouin.¹⁶

It is known that an electron injected into a homogeneous magnetic field, H , perpendicularly to it is forced into a circular path of the radius

$$r = mv/eH \quad (13)$$

and continues its motion with the uniform angular velocity

$$\omega_m = v/r = He/m = 17.6 \times 10^6 H \text{ (sec}^{-1}\text{)} \quad (14)$$

where e and m are the charge and the mass of an elec-

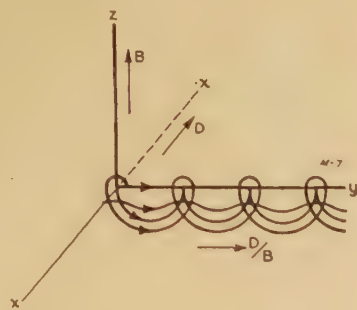


Figure 7. Electron motion in combined electric and magnetic fields with different initial velocities

tron, and v is its initial velocity. No exchange of energy between the moving electron and the magnetic field takes place.

If an electron moves in a combination of mutually perpendicular magnetic and electric fields, H and D (Figure 7), its path will be cycloidal with the general direction of the motion perpendicular to both fields; in other words, the electron drifts along the equipotential surfaces. Its average drift velocity, is D/H ; however, its circular velocity as viewed from the center of the circle generating the cycloid is the same as in equation 14. This can be rewritten as

$$f = \frac{\omega_m}{2\pi} = 2.8 \times 10^6 H \text{ (cycles per second)} \quad (15)$$

The latter expression strikingly suggests the idea that electron motion in a magnetic field may be utilized for the generation of ultrahigh-frequency oscillations. Indeed, even with easily realizable magnetic fields, such as $H = 1,000$ gauss, the frequency of the rotational motion of electrons becomes $f = 2.8 \times 10^{10}$ cycles per second which corresponds to the wave length.

$$\lambda = \frac{10,700}{H} = 10.7 \text{ centimeters} \quad (16)$$

The problem is to find the proper means of transferring the energy of the electrons moving in an electric and magnetic field to an oscillating circuit. This problem is solved in the magnetron.

In a cylindrical magnetron with an axial magnetic field and the potential E applied to the anode, the electric field is distributed radially. Also, in this case, electrons describe a cycloidal path with its generating circle rolling around the cathode (Figure 8). The average motion of electrons is again along equipotential surfaces which in this case are circles. Its average velocity is

$$\omega_{avg} = D/Hr \quad (17)$$

The values of the anode potential E and the magnetic field H at which the electrons just graze the anode are called critical values. The relation between the anode critical voltage, the magnetic-flux density, and the anode radius was derived by Doctor Hull:

$$r_a = \frac{6.72 \sqrt{E_c}}{H_c} \quad (18)$$

More exactly, if the cathode has a finite radius r_c , the critical condition is

$$r_a \left(1 - \frac{r_c^2}{r_a^2} \right) = \frac{6.72 \sqrt{E_c}}{H_c} \quad (19)$$

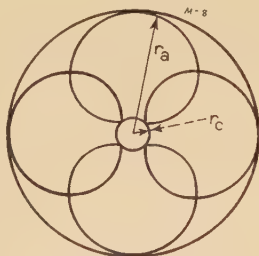


Figure 8. Electron motion in a nonoscillating magnetron with nearly critical values of D and B

Three types of magnetron oscillators are discriminated:

1. Negative resistance or dynatron oscillation.
2. Transit-time oscillations of the first order.
3. Transit-time oscillations of higher orders.

NEGATIVE-RESISTANCE OR DYNATRON OSCILLATIONS

These oscillations are also called quasi-stationary and sometimes Habann oscillations in foreign literature. The nature of these oscillations can be understood from the following simple experiment.¹⁷ In a two-segment magnetron (Figure 9) we first apply the same d-c voltage to both segments, the magnetic field being approximately 1.5 times its critical value; then, we shall increase the potential of one half in steps and decrease the potential of the other half in similar steps. If we measure the current to each half and plot their difference against potential difference between two segments, we shall find that the current curve has a negative-resistance slope. This is a sure sign that the tube can generate oscillations. Their frequency is controlled by that of the oscillating circuit connected between the two segments. The electronic mechanism of this kind of oscillation has been studied by many authors both theoretically and experimentally. The general picture is approximately this: When both segments are at the same potential, the electrons leaving the filament under the influence of the anode voltage describe circles, and, because the potential is below its critical value, they return to the filament; no current flows to the anode. If, however, one segment has a higher potential than the other, as happens during oscillation, the potential distribution within the magnetron is as shown in Figure 10. If potential variation is much slower than the rotational frequency of the electrons, the latter will describe cycloid-like paths with the general tendency to drift along the equipotential surfaces, so that finally electrons arrive at the vicinity of the slot. There, they may strike either the positive or the negative segment. Theory and experiments show that, at certain radio-frequency voltage amplitudes, more electrons will fall on the negative than on the positive half; with it, a-c current flows against a-c voltage, which means that there will be negative resistance, or that oscillations will be sustained. The negative-resistance oscillations for good efficiency require a high magnetic field; hence, high voltages and small anode diam-

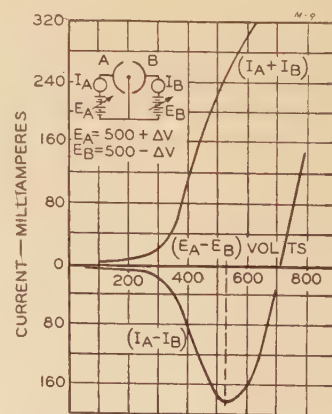
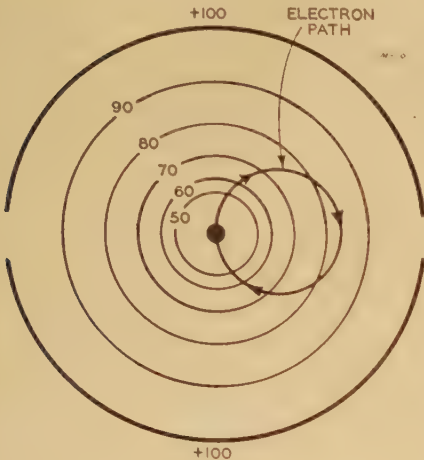


Figure 9. Static characteristics of a two-segment negative-resistance magnetron

eters. These magnetrons are suitable for the generation of wave lengths above 50 centimeters. They can deliver power of several hundred watts at a fairly good efficiency, 60 per cent and higher.

TRANSIT-TIME OSCILLATIONS OF THE FIRST ORDER

This kind of oscillation is somewhat similar in nature to Barkhausen oscillation in a triode. Its frequency is



practically independent of external circuit conditions. However Barkhausen generators are capable of deliv-

Figure 10 (left). Potential distribution and a typical electron path in a two-segment negative - resistance magnetron

ering power only of a fraction of a watt, whereas the output from this type of magnetron oscillator may amount to several watts. The magnetic field for these oscillations is equal to its critical value. The oscillating cycle is equal approximately to the calculated electron transit time; that

is, to the time of its complete revolution in the magnetic field; this indicates that the generated wave length is $\lambda = 10,700/H$.

The electronic mechanism may be described as follows: In the absence of a-c voltage between segments, the electrons will describe a complete circular path almost touching the anode and return to the cathode. With some a-c voltage the uniform radial electric field will be distorted by the superposition of oscillating transversal field between the two segments (Figure 11). This will be particularly strong in the vicinity of the slots. Now, those electrons which pass in front of the gaps with the positive a-c field receive an additional acceleration, the radii of their paths become greater (equation 13), and

they readily fall on the segment with higher potential, thus contributing to the tube loss.

On the other hand, those electrons which pass the gaps through an adverse field will be decelerated and give up a part of their energy to the electric field; that is, they can sustain oscillation. The decelerated electrons continue their motion around the cathode on a curve with a smaller radius than originally and may again and again contribute part of their energy to the oscillating field, until they fall out of phase. It was found experimentally¹⁸ that a slight angle between the tube axis and the magnetic field improves tube operation, because a longitudinal spiral motion of electrons helps them to eliminate de-phased electrons. A similar effect can be produced by applying a longitudinal electric field.¹⁹

TRANSIT-TIME OSCILLATIONS OF HIGHER ORDER

The magnetrons designed for this type of operation usually have more than one pair of anode segments, and the operating magnetic field is approximately 60 to 70 per cent higher than critical. The electronic mechanism is here an intermediate one between those of the two previous modes of oscillations. Unlike the occurrences in the transit-time magnetrons of the first order, here the electrons describe several sharp convolutions before they reach the vicinity of the slot with adverse electric field,

where they surrender part of their energy used for sustaining oscillations (Figure 12). Correspondingly, their precessional frequency, $\omega_{avg} = D/rH$ —not the basic electron frequency, $\omega_m = k/H$ (see equation 14)—must be in resonance with the radio-frequency voltage. The amplitude of the basic frequency is here too small to be of importance, since because of the high magnetic field the primary electron paths are sharply curled.

Figure 11. Transverse electric field in a transit-time magnetron of the first order

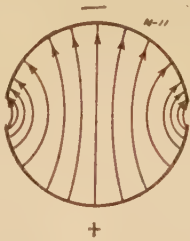
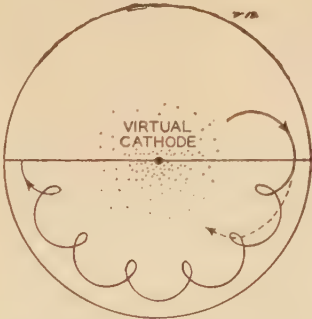


Figure 12. A typical electron path in a transit-time magnetron of higher orders



The ration $n = \omega_{avg}/\omega_m$ determines the order of oscillations. One may also consider that these oscillations are a result of synchronous rotation of an electron cloud filling the magnetron with one of the rotating components of the radio-frequency voltage and that a resonance exists between the radio-frequency voltage and variation of the outer form of the cloud. In Groos's book, page 61,

experimental curves,¹⁵ efficiency versus oscillation order, n , are given (Figure 13); they show that efficiency improves with the magnitude of order and also that improvement can be achieved by splitting the anode into more than two segments. For a multiple magnetron Groos gives (page 59)

$$\lambda = 942 r_a^2 H / p E \quad (20)$$

where p is the number of pairs of segments and E the anode voltage. An optimum value of H is obtained from the relation

$$\frac{H_{\text{opt}}}{H_{\text{critical}}} = \frac{np}{2} \sqrt{\frac{1}{np-1}} \quad (21)$$

By combining expressions 21, 20, and 19 the expression for the wave length as function of operational and structural parameters becomes

$$\lambda = \frac{3,160 n r_a \sqrt{\frac{1}{np-1}}}{E_a} \quad (22)$$

For good efficiency n must not be less than 10.

VELOCITY-MODULATION GENERATORS

In 1935 Arseniewa-Heil and Heil, in their paper,²¹ "A Novel Method of Generating Short Continuous Electromagnetic Waves of High Intensity," for the first time described a principle which is now called in our literature velocity modulations. Independently and almost simultaneously the

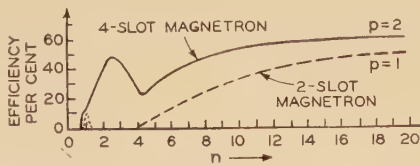


Figure 13. Experimental curves—efficiency versus order of oscillations in two- and four-segment transit-time magnetrons

Varian brothers in this country invented their famous "Klystron" which is also a velocity-modulation generator of an advanced design.²²

A novel feature of the velocity-modulation generators, as described by the Heils, consists in rhythmical precipitation of closely packed groups of electrons, previously accelerated to a high velocity, against an adverse electric field. In result, the energy rhythmically transmitted by electrons to the field is apt to produce and sustain oscillations in the circuit associated with the electric field.

Another novel feature consists of the manner of collecting electrons in closely packed groups. Instead of the conventional opening and closing of the gate by a negative-control grid in a triode, the velocity-modulation generators have the following mechanism (Figure 14): Two pairs of narrowly spaced grids are separated by a distance, S , and are interposed in the path of a beam of electrons; these are accelerated from the cathode by high d-c voltage applied between the grids and the cathode. All four grids are at the same d-c potential. The electrons forming a continuous beam between the

cathode and the first grid have the same velocity while they enter the first gap. A low radio-frequency voltage produced by an oscillating circuit is applied across the first gap. Therefore, some of the electrons, while traversing the gap, are slightly accelerated; some maintain their velocity; and some are decelerated. Then electrons with different velocities enter the long "drift" space with no electric field (Faraday cage) where speedy electrons catch up with slow ones, so that, after certain

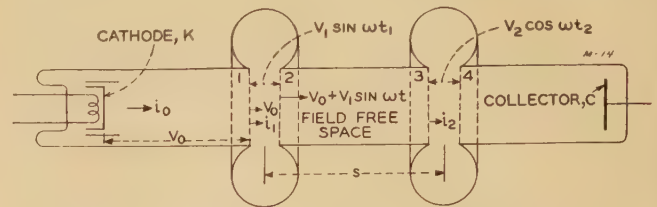


Figure 14. Diagram of velocity-modulation generator

traveling distance, they are collected in groups or "bunches", but only for a short time. If permitted to travel farther, they become "debunched," then again bunched, and so on. With a given distance S between the gaps, one can adjust operating voltages, so that the electrons will reach and traverse the second gap just while they are closely packed. Then, as previously stated while crossing the gaps in rhythmical sequence against the field produced by another oscillating circuit, they sustain the oscillations. The exhausted electrons continue their flight beyond the second gap and are intercepted by a collector. Obviously, the frequency of both oscillating circuits must be the same.

All quantities involved in the described electronic mechanism are connected by the relation

$$r = \frac{S \omega V_1}{v_0^2} = \frac{S \omega}{v_0} \times \frac{V_1}{v_0} \quad (23)$$

Here S is the distance between the gap centers, V_0 is the average velocity, and v_1 the amplitude of modulated velocity. It has been shown by Doctor Webster²³ that variation of r by varying one or several quantities in equation 22 causes changes in the shape of the electron wave passing through the output or "catcher" gap; hence, in the form of the current, i , through the gap.

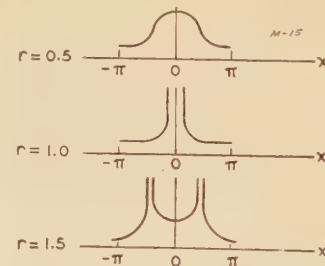


Figure 15. Wave forms of current in velocity-modulation generator

The typical current forms are shown in Figure 15. Theoretical maximum efficiency of 58 per cent corresponds to $r=1.84$; however, the practical value obtained is considerably lower, usually not over 20 per cent. The pronounced peaks in the current curves witness that the

velocity-modulation generators are suitable for production of harmonic oscillations: that is, for frequency multiplication. In this case the output circuit, the catcher, is to be tuned to a harmonic of the input circuit, the buncher.

As implied by the preceding discussion, the electron transit time is not critical to the operation of a velocity-modulation generator, as the electrons without harm to oscillations may stay in the drift space during several cycles.

One must realize that because of the extremely high frequencies the conventional oscillation circuits are here difficult to design. The Varian brothers incorporated in their generator so-called hollow-body or cavity resonators. These, although known since 1897 through a paper by Lord Raleigh,²⁴ only recently came to general knowledge and use because of the work of Doctor Hansen.²⁵

It has been shown theoretically and experimentally that a space totally enclosed by a metallic conductor, such as a sphere, cylinder, prism, and the like, may become a seat of vigorous electromagnetic oscillations, if these are properly excited. Because of a basic rule that the tangential component of the internal electric field at the conductor is zero, only certain discrete frequencies or wave lengths can develop, and there always exists a minimum or cutoff frequency. The values of the resonant frequencies are determined by the size and shape of the enclosure and can be calculated. The longest or cutoff wave length is always comparable at least to one of the main dimensions of the resonator. Thus, for a sphere, $\lambda = 2.28 r$; for a cylinder, $\lambda = 2.61 r$, where r is the radius of the sphere or of the cylinder.

The great advantage of cavity resonators as compared to other forms of oscillating circuits is their extremely high Q . This is the result of low resistance loss and of the complete absence of radiation losses, because there is no external electromagnetic field. For cavity resonator, Q is equal to the ratio

$$Q = \frac{\text{volume of inner space}}{\text{surface area by } \delta}$$

Here δ is the thickness of the inner conducting skin of the wall; it can be calculated from equation 41 given by Doctor Weber.¹ Values of Q as high as 50,000 can be obtained with cavity resonators. Another advantage of these oscillators is a high shunt impedance permitting a better matching of the load even at extremely high frequencies.

REFERENCES

1. Ultrashort Electromagnetic Waves—I. Electromagnetic Theory, **Ernst Weber**. *Electrical Engineering*, volume 62, March 1943, pages 103-12.
2. Ultrashort Electromagnetic Waves—II. Transmission-Line Theory, **John R. Ragazzini**. *Electrical Engineering*, volume 62, April 1943, page 20.
3. Ultrahigh-Frequency Generation, **I. E. Mouromtseff, R. C. Retherford, J. M. Findlay**. *Electronics*, April 1942, page 10.
4. Three New Ultrahigh-Frequency Triodes, **K. C. De Walt**. *Proceedings Institute of Radio Engineers*, volume 29, September 1941, page 475.
5. A New Type of Ultrashort-Wave Oscillator, **I. E. Mouromtseff, H. V. Noble**. *Proceedings Institute of Radio Engineers*, volume 20, August 1932, page 1328.

6. Tuned-Grid Tuned-Plate Oscillator, **I. E. Mouromtseff**. *Communications*, volume 20, August 1940, page 7.
7. Triode Oscillators for Ultrashort Wave Lengths, **M. R. Gavin**. *Wireless Engineer*, volume 16, number 189, June 1939, page 287.
8. Large Signal High-Frequency Electronics of Thermionic Vacuum Tubes, **Chao Chen Wang**. *Proceedings Institute of Radio Engineers*, volume 29, April 1941, page 200.
9. Input Resistance of Vacuum Tubes as Ultrahigh-Frequency Amplifiers, **W. R. Ferris**. *Radio Corporation of America Radiotron Publication ST-34*, January 1936.
10. Shortest Waves Obtainable With Valve Generators, **H. Barkhausen, K. Kurz**. *Physikalische Zeitschrift* (Leipzig, Germany), volume 21, January 1920, pages 1-6.
11. The Effect of a Uniform Magnetic Field on the Motion of Electrons Between Coaxial Cylinders, **Albert W. Hull**. *Physical Review*, volume 18, number 1, July 1921, page 31.
12. Über Eine Methode zur Erzeugung von Sehr Kurzen Wellen, **A. Zacek**. *Zeitschrift für Hochfrequenztechnik*, volume 32, November 1928, page 172.
13. Beam Transmission on Ultrashort Waves, **Hidetugu Yagi**. *Proceedings Institute of Radio Engineers*, volume 16, June 1928, page 715.
14. On the Short-Wave Limit of Magnetron Oscillation, **Kinjiro Okabe**. *Proceedings Institute of Radio Engineers*, volume 17, April 1929, page 652.
15. Einführung in Theories und Technik der Dezimeterwellen, **Otto Groos**. S Hirze, Leipzig, Germany, 1937.
16. Theory of the Magnetron, **L. Brillouin**. *Physical Review*, volume 60, second series, September 1, 1941.
17. Magnetron Oscillator for the Generation of Frequencies Between 300 and 600 Megacycles Per Second, **G. R. Kilgore**. *Proceedings Institute of Radio Engineers*, volume 24, August 1936, page 1144.
18. Magnetostatic Oscillators for Generation of Ultrashort Waves, **G. R. Kilgore**. *Proceedings Institute of Radio Engineers*, volume 20, November 1932, page 1744.
19. Description and Characteristics of the End-Plate Magnetron, **E. G. Linder**. *Proceedings Institute of Radio Engineers*, volume 26, March 1936, page 346.
20. A New Circuit for the Production of Ultrashort-Wave Oscillations, **H. N. Kozanowski**. *Proceedings Institute of Radio Engineers*, volume 20, June 1932, page 957.
21. Eine Neue Methode zur Erzeugung Kurzer Ungedämpfter Elektromagnetischen Wellen von Grosser Intensität, **A. Arseniewa-Heil, O. Heil**. *Zeitschrift für Physik* (Berlin, Germany), volume 95, numbers 11, 12; July 1935, page 752.
22. A High-Frequency Oscillator and Amplifier, **R. H. Varian, S. F. Varian**. *Journal of Applied Physics*, volume 10, May 1939, page 321.
23. Cathode-Ray Bunching, **David L. Webster**. *Journal of Applied Physics*, volume 10, July 1939, page 503.
24. Lord Raleigh. *Philosophical Magazine*, volume 43, fifth series (number 1), number 261, February 1897, page 125.
25. On Resonators Suitable for Klystron Oscillators, **W. W. Hansen, R. D. Richtmayer**. *Journal of Applied Physics*, volume 9, March 1939, page 189.



This tank commander wears a throat microphone around his neck which picks up words directly from the speaker's vocal cords and eliminates extraneous noises. The throat microphone, produced by Western Electric Company, consists of a snugly fitting "dog collar" with two buttons which press gently against the side of the throat

INSTITUTE ACTIVITIES

Role of Engineers in War Keynote of Northeastern District Meeting

A successful wartime technical meeting of the North Eastern District was held in Pittsfield, Mass., April 8 and 9, 1943, with headquarters in the Wendell Hotel. Eight technical sessions and conferences and a general session were held during the two days of the meeting, which was preceded by a tri-Sectional technical-paper competition for younger engineers on the evening of April 7. The presentations at each of the sessions and conferences exemplified the part taken by electrical engineers in aiding the war effort. The total registered attendance was 318, as analyzed in the accompanying table.

GET-TOGETHER DINNER

One of the features of the meeting was an after-dinner address on Thursday evening, "Railroad Transportation in the Present Emergency," by C. E. Smith, vice-president of the New York, New Haven, and Hartford Railroad. Speaking from a long and varied experience in the transportation field, Mr. Smith began with the early history of the New York, New Haven, and Hartford electrification, which started in 1895 with an experimental and research installation from Hartford down through New Britain as far as Bristol, Conn. He said that the traffic on American railroads in 1942 had exceeded by 33 per cent the highest peak in history and this was being handled successfully as a result of the expenditure of \$12,000,000,000 for additions and improvements to the American railroads between the two World Wars. Increased traffic was attributed to submarine attacks on the Atlantic seaboard and to the attack on Pearl Harbor, as well as the cutting off of the rubber supply and gasoline rationing. He stated that the movement to the Pacific coast of 600,000 troops, fully equipped, within the few weeks after the attack of Pearl Harbor would go down in history as one of the greatest troop movements of all times. Interesting statistics were given regarding the equivalent number of tank cars (700) required to transport the same number of barrels of oil as a modern naval tanker (150,000 bbls—6,300,000 gals), as well as a comparison of the number of troops all over the United States now traveling per month, as compared with the greatest number traveling per month during the World War. He also referred to the number of trains and cars now required to transport an infantry division and an armored division. All of these feats are being accomplished with approximately 200,000 out of 1,000,000 railroad employees in the armed services. Mr. Smith attributed these feats to the fact that the railroads got together at the

beginning of the war and appointed control committees, with the result that there has been no indication of congestion or breakdown. Four days after the invasion of Poland the railroad executives met and resolved to do whatever was necessary to handle the emergency traffic that might result from the war. He said that full cooperation of the American Government has been obtained and that there was no sentiment in Washington for the Government to take over the railroads, as in the case of the last war.

The speaker was introduced by S. T. Maunder, former chairman of the Pittsfield Section. Preceding the dinner a vice-presidential reception was accorded Doctor and Mrs. K. B. McEachron at the Wendell Hotel.

GENERAL SESSION

Motion pictures and data on sleet damage on overhead lines due to a storm in the Berkshire Mountains last December were presented by J. F. Burt, Western Massachusetts Electric Company. As a program for restoring service, Mr. Burt explained that the town's selectmen designated the most worthy cases where service should be restored first. Areas out of service were chartered first in red and then in blue, as service was restored. He urged that the damage to trees should be cleared up, notwithstanding a manpower shortage, as it presented a considerable fire hazard.

President Osborne addressed the session on the subject of "The Engineer's Interest in City Planning," which served as an introduction to the conference on city and regional planning that followed. He explained that electrical engineers have a very direct stake in city planning beyond their stake as citizens. In converting from war to peace, rapid changes would occur in many communities, which would not necessarily be prosperous after the war. This was illustrated by Doctor Houser's classifications in regional planning district 1, which emphasized the point that consideration must be given to the communities after the war and that the postwar positions of communities must be analyzed. As to how much might be accomplished, a great deal depends upon the future of nations, national economic planning, the positions of industries, and state planning. In the address Doctor Osborne pointed out that community planning is the problem of the entire community, which should have official planning agencies, and that lack of appreciation and public support would prevent giving the most effective service. In conclusion, he said that engineers have

a double stake in municipal planning, through their manufacturing organizations and public utilities and as citizens.

CONFERENCE ON CITY AND REGIONAL PLANNING

The conference was opened with an address of welcome by the Honorable James Fallon, mayor of Pittsfield. A feature of the conference was an address on the subject of "Regional Development Through Industrial Research" by L. W. Bass, director of the New England Industrial Research Foundation. Other notable speakers included Miss Elisabeth M. Herlihy, chairman and executive secretary, Massachusetts State Planning Board; The Honorable Roger Lowell Putnam, mayor of Springfield, Mass., and director of the New England Council; William Stanley Parker, member and former chairman of the Boston City Planning Board; Fred Fisch, director of traffic and city planning, Schenectady, N. Y.; and Professor F. J. Adams, chairman of the housing committee on joint projects, Massachusetts Institute of Technology. The conference was the fourth on this subject held at national and District meetings. President Osborne presided during the meeting.

TRI-SECTIONAL COMPETITION

Wednesday evening a technical-paper competition among the Schenectady, Lynn, and Pittsfield Sections for the younger engineers was held in the Berkshire Museum. First prize of \$15 was awarded

Analysis of Registration at Pittsfield

Classification	Pittsfield Section	District 1*	Other Dis- tricts	Totals
Members.....	96.....	99.....	22.....	217
Enrolled Students.....	1.....	28.....	0.....	29
Men guests.....	7.....	40.....	15.....	62
Women guests.....	5.....	5.....	1.....	11
Totals.....	109.....	172.....	38.....	319

* Outside Pittsfield.

North Eastern District Technical Meeting Attendance 1933-1943

Date	Location	Attend- ance
1943—Apr. 8-9.....	Pittsfield, Mass.....	319
1942—Apr. 29-May 1.....	Schenectady, N. Y.....	481
1941—Apr. 30-May 2.....	Rochester, N. Y.....	355
1939—May 3-5.....	Springfield, Mass.....	439
1938—May 18-20.....	Lenox, Mass.....	417
1937—May 5-7.....	Buffalo, N. Y.....	352
1936—May 6-8.....	New Haven, Conn.....	310
1934—May 16-18.....	Worcester, Mass.....	337
1933—May 10-12.....	Schenectady, N. Y.....	431

Present at the get-together dinner April 8 of the AIEE Northeastern District technical meeting were (left to right) M. S. Oldacre, Commonwealth Edison Company, who spoke at the power transmission and



distribution meeting; R. T. Henry of the Buffalo General Electric Company, who spoke at the measurements and instrument transformer meeting; M. O. Troy, commercial vice-president of General Electric Company, and V. M. Montsinger of General Electric Company's power-transformer engineering department, Pittsfield.

Awards for last years' papers were presented at the dinner

to J. H. Spencer of the Pittsfield Section for his paper entitled "Bridge Building in the Laboratory—Story of the Tacoma-Narrows Bridge." Second prize of \$10 was awarded to H. J. Mason, also of the Pittsfield Section, for his paper entitled "Engineering, the Handmaiden of Civilization." The Pittsfield Section won the competition this year with a total point score of 1,344, and thus, having won two times out of three, gained permanent possession of the plaque awarded by P. L. Alger. The Lynn Section was second with 1,272 points, and the Schenectady Section third with 1,182 points. In judging the awards equal weight was given to written papers and oral presentations. In judging the oral presentations assistance was given the three judges by the audience.

TECHNICAL SESSIONS

Papers presented in each of the technical sessions exemplified the aid which electrical engineers are giving to the war effort. For example, in the session on power transmission and distribution, papers on "Use of Equivalent Annual Ambient Temperature in Overloading Transformers and Voltage Regulators," by M. S. Oldacre of the Commonwealth Edison Company, and "Electric Rating of Overhead Line Wire," by Myron Zucker, on leave from the Detroit Edison Company, are both directed toward the conservation of copper and other critical materials. In the session on measurements and instrument transformers G. Camilli of the General Electric Company described new designs of potential transformers which have been reduced greatly in size and weight. This has been accomplished partly by designing the porcelain bushings to permit expansion of the liquid inside the bushings rather than in the transformer case. Porcelain is a noncritical material. In the same session R. T. Henry, chairman of the subcommittee on circuit breakers, switches, and fuses, presented an "Interim Report on Application and Operation of Circuit Breakers and Switchgear." In presentation Mr. Henry explained that savings in critical materials could be effected in several ways. He brought out that in the design of bus structures, by feeding in at a central point and

taking off of heavily loaded feeders near the center and lightly loaded feeders at the ends of the bus, the copper required could be tapered off toward the ends. In some cases the silver plating of contacts and connections would permit using the next smaller size apparatus. He also referred to painting for favorable radiation.

In the plastics session, characteristics and properties of thermoplastic materials, as well as their uses and applications, were discussed by the representatives of several large manufacturers in this field, including Turner Alfrey Jr., of the Monsanto Chemical Company; C. W. Blount of the Bakelite Corporation; and W. S. Larson and P. B. Leverette of the General Electric Company. As new plastic materials quickly found many applications in the electrical field before the war, they likewise have quickly found wide and varied applications in the field of military equipment. Several of the thermoplastics have important uses as a substitute for rubber.

TECHNICAL CONFERENCES

Similarly, in the technical conferences most of the presentations were related to the war effort. In the conference for industrial operators of electrical equipment, T. M. Linville of the General Electric Company presented valuable information on the methods of organizing and holding clinics for industrial operators. He described the purpose of the clinics as stated by the War

Production Board, the arrangements made by the WPB for financial and other assistance, local arrangements and program topics, and the novel organization of the Schenectady clinic. Programs of the Northeastern New York War Production Conference, to be held in Schenectady April 15, 1943, were distributed. In conclusion, Mr. Linville referred to the clinics which so far had been found popular, with the attendance in every case exceeding expectations. In this conference the protective lighting in industrial plants was described by H. E. Mahan of the General Electric Company. Mr. Mahan's presentation was illustrated with lantern slides showing fence lighting, the lighting of entrances, and the proper placing of luminaires, which are effective measures against sabotage.

Another conference dealt with the subject of electric welding and brazing, and still another dealt with the subject of electronics and communications. In this conference a large part of the discussion was devoted to the elimination of radio noise in aircraft. D. K. Kinsey of the Consolidated Vultee Aircraft Company explained the problems arising in the construction of small planes with a wooden fuselage because of the loss of shielding and restrictions against the use of conduit by the War Production Board. C. W. Frick of the General Electric Company described the characteristics of the different types of filters and analyzed the considerations for installing filters to minimize the disturbance voltages found in radio circuits. This presentation was followed by a demonstration of the reduction in noise by S. W. Zimmerman of the General Electric Company. With the aid of an oscilloscope and a radio receiver, the effects of the application of a π -type filter across the terminals of a standard airplane generator were observed and heard.

TECHNICAL PERSONNEL IN WARTIME

The concluding feature of the meeting was an important conference on wartime problems of technical personnel with vice-president K. B. McEachron presiding. The meeting brought up to the minute the latest methods and regulations for the securing and training of technical personnel needed by the Army and the Navy. This

AIEE president and vice-president confer with the mayor of Pittsfield at conference on city and regional planning during AIEE Northeastern District technical meeting April 8 and 9 in that city. Left to right are: K. B. McEachron of General Electric Company, AIEE



vice-president; James Fallon, mayor of Pittsfield; and H. S. Osborne of American Telephone and Telegraph Company, AIEE president

information was given in addresses by Colonel Herman Beukema, director of the Army Specialized Training Division, and Joseph W. Barker, Special Assistant to the Secretary of the Navy, respectively. The point of view of the War Manpower Commission's technical program for war industries was given in an address by William C. White, regional adviser for the war-training program, and dean of engineering at Northeastern University. He indicated that 25 per cent of the facilities of engineering schools are reserved for training for industries. Questions from the audience in regard to the programs were answered by the speakers. After a brief recess man-power problems in the manufacturing and operating companies were described by M. M. Boring of the General Electric Company and A. J. Mundt of the Western Union Telegraph Company. Man-power problems in the technical colleges were discussed by F. J. Adams, Worcester Polytechnic Institute; S. B. Wiltse, Rensselaer Polytechnic Institute; and C. L. Dawes of Harvard University. The meeting concluded with a discussion of technical man-power problems after the war by A. G. Conrad of Yale University; I. A. Terry of the General Electric Company; and C. L. Dawes.

Summer Technical Meeting Will Cover Wartime Problems

Arrangements are being made for the national technical meeting to be held in Cleveland, Ohio, June 21-25, 1943. Meeting headquarters will be in the Hotel Cleveland. In accordance with AIEE wartime policies defined (*EE*, Sept. '42, p. 477), all programmed social activities will be omitted, and solicited technical papers will be closely related to the war effort. In addition to the annual meeting; conference of officers, delegates, and members; and one general session, tentative arrangements have been made to hold 24 sessions and conferences.

TECHNICAL SESSIONS AND CONFERENCES

Many of the sessions and conferences will deal with the problems which have arisen in connection with power supply under war conditions, with the objective of obtaining the maximum use of existing equipment and apparatus to conserve critical materials. A few of the conferences will treat the postwar problems. In addition, it is expected that several more proposed wartime guides for the application and operation of electrical equipment will be made available. Some of the sessions tentatively scheduled will treat the following subjects: automatic stations, teaching electrical communication, power generation, governors, relaying, switching equipment and related subjects,

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held at the Cleveland Hotel, Cleveland, Ohio, at 10:00 a.m. on Tuesday, June 22, 1943. This will constitute one session of the national technical meeting.

At this meeting, the annual report of the board of directors and the report of the committee of tellers on the ballots cast for the election of officers will be presented.

Such other business, if any, as properly may come before the annual meeting may be considered.

(Signed) H. H. HENLINE
National Secretary

carrier current and miscellaneous subjects, power transmission and distribution, wartime influences on lighting, mercury-arc rectifiers, teaching aids in specialized training, experiences and problems in military specialized training, maintaining contact with those in the armed forces, welding control and power supply, industrial power applications, selected subjects, standards and the Americas, agricultural electrification, symposium on synchronous machinery, electrical machinery, high-frequency heating, and aeronautical electrical engineering.

SECTION

Joint Georgia Meeting of AIEE and IAEI

The Georgia Section of AIEE is co-operating with the Georgia chapter of the International Association of Electrical Inspectors in arranging a two-day meeting (May 1-2, 1943) of maintenance electricians and mechanics from over 600 Georgia industrial plants.

The meeting program will be directed toward aiding men in supervising and maintaining electrical equipment. Some of the subjects to be covered are: maintenance of wiring systems, wartime application and maintenance of motors, selection and maintenance of motor control, electrical-equipment circuit protection, power factor and its improvement, lamp and fixture maintenance in industry, wartime changes in the national electrical code, and getting the most from the "power dollar."

Organization of Subsections Eases Meeting Transportation Problem

Organization of subsections and smaller technical groups within Sections of the AIEE is helping to solve the problem of members being able to attend AIEE meetings under the limited transportation condi-

tions of wartime. The Sections committee under the chairmanship of E. T. Mahood has prepared a pamphlet on the organization of subsections which is available to Sections and members who are interested. Copies of the pamphlet may be obtained from AIEE headquarters. In charge of the subcommittee on development of subsections are E. W. Schilling, chairman, and C. A. Faust.

Six subsections and 15 technical groups are in operation at the present time. They are:

Chicago: *Power group*, F. D. Troxel, chairman, Sargent and Lundy. *Industrial group*, A. D. Pettee, chairman, General Cable Corporation. *Communications group*, A. B. Bronwell, chairman, Northwestern Technological Institute, Evanston, Ill.

Cincinnati: *Dayton subsection*, L. J. Fritz, chairman, Ohio Bell Telephone Company, and J. W. Gerke, secretary.

Cleveland: *Technical meetings*, William G. Hall, chairman, Reliance Electric and Engineering Company, and D. Ramadasoff, secretary, National Carbon Company.

Columbus: *Zanesville subsection*, executive committee, J. O. Fenwick, chairman, Line Material Company, and J. G. Everhart, secretary, Line Material Company.

Madison: *Rock River Valley subsection*, A. M. Forman, chairman, Continental Electric Company, Rockford, Ill., and C. V. Bullen, secretary, Barber-Colman Company, Rockford, Ill.

Michigan: *Round-table meetings*, Ellis D. Kane, chairman, Detroit (Mich.) Edison Company.

New York: *Transportation group*, E. E. Dorting, New York City Transit System, chairman, and Alexander Shirreffs, Westinghouse Electric and Manufacturing Company, secretary. *Power group*, R. T. Oldfield, Public Service Commission, chairman, E. T. Farish, Westinghouse Electric and Manufacturing Company, secretary. *Communication group*, H. M. Saunders, Western Union Company, chairman, and R. E. Smith, Federal Telephone and Radio Corporation, secretary. *Illumination group*, H. L. Logan, chairman, Holophane Company, Inc. *Basic-science group*, R. E. Crane, Bell Telephone Laboratories, Inc., chairman, and G. T. Harness, Columbia University, secretary.

Philadelphia: J. A. Thielman, general chairman, discussion group committee, Philadelphia Electric Company. *Communications discussion group*, A. F. Godsho, chairman, Bell Telephone Company of Pennsylvania, and M. L. Lehman, secretary, American Telephone and Telegraph Company. *Foremen's discussion group on electrical problems*, H. A. Eysenbach, Jr., chairman, Cramps Shipbuilding Company, and A. E. Pringle, 2nd, secretary, Pringle Electrical Manufacturing Company. *Industrial-practice discussion group*, J. R. Fletcher, chairman, E. G. Budd Manufacturing Company, and H. W. Moser, secretary, the Ballinger Company. *Instruments and measurements discussion group*, W. R. Clark, chairman, Leeds Northrup Company, and E. G. Howe, secretary, General Electric

Future AIEE Meetings

National Technical Meeting
Cleveland, Ohio, June 21-25, 1943

National Technical Meeting
Salt Lake City, Utah, September 2-4, 1943

Company. *Power systems discussion group*, B. W. Wyman, chairman, General Electric Company, and O. B. Vikoren, secretary, Philadelphia Electric Company.

Toronto: *Hamilton, Ont., discussion group* (subsection), W. R. Harmer, chairman, Hydro-Electric Power Commission of Ontario, Toronto, and Alex M. Weir, secretary, Square D Company, Ltd., Toronto.

Urbana: *Illinois Valley subsection*, E. W. Stone, Central Illinois Light Company, Peoria, Ill., chairman, and F. A. Ericzon, secretary-treasurer, Central Illinois Light Company, Peoria, Ill.

Utah: *Idaho technical committee* (subsection), R. E. Alworth, acting chairman, Idaho Power Company, Boise, Idaho, and Frederic S. Beale, secretary, Idaho Power Company, Boise, Idaho.

STANDARDS . . .

Revised Editions Now Available

Transformers, Regulators, and Reactors. An approved American Standard for "Transformers, Regulators, and Reactors," C57.1, C57.2, and C57.3, dated 1942, is now available. This supersedes the preliminary edition of a pamphlet of the same title and number issued in 1940. The pamphlet also contains the American Recommended Practices on "Test Code for Transformers" and "Guides for Operation of Transformers and Regulators." The various types of apparatus covered in the standard are as follows: distribution, power and regulating transformers and reactors, instrument transformers, constant-current transformers of the moving-coil type, step-voltage and induction-voltage regulators, current-limiting reactors, general-purpose specialty transformers. Copies of the standard may be obtained from AIEE headquarters, 33 West 39th Street, New York, N. Y., at a cost of \$1.00 per copy, no discount to anyone.

Railway Motors. An approved American Standard for "Rotating Electrical Machinery on Railway Locomotives, and Rail Cars and Trolley, Gasoline-Electric and Oil-Electric Coaches," C35.1—1943 (AIEE number 11) is now available. This American Standard supersedes the tentative standard issued by the AIEE in 1937. Copies may be obtained from AIEE headquarters, 33 West 39th Street, New York, N. Y., at a cost of 50 cents per copy with discount of 50 per cent to AIEE members on single copies.

Measurement of Test Voltages in Dielectric Tests. A new American Standard for "Measurement of Test Voltage in Dielectric Tests" is now available. This pamphlet (AIEE Standard 4—American Standard C68.1) supersedes the former 1940 edition of AIEE number 4. It was developed under the auspices of the Institute's committee on instruments and measurements which was identical with the American Standards Association sectional committee C68 on Sphere-Gap Standards. In this

standard are set forth methods for the measurement of test voltages and wave shapes in dielectric tests of insulating materials. These are in three classes: puncture tests; flashover tests, and voltage-proof tests, which may involve the use of alternating current, direct current, or surges from surge generators. Copies of the pamphlet may be obtained from AIEE headquarters, 33 West 39th Street, New York, N. Y., at a cost of 40 cents per copy with discount of 50 per cent to AIEE members on single copies.

Graphical Symbols. Three new American Standards for graphical symbols are now available as follows:

(a). *Graphical Symbols for Power, Control, and Measurement*, Z32.3.

(b). *Graphical Symbols for Telephone, Telegraph, and Radio Use*, Z32.5.

(c). *Graphical Electrical Symbols for Architectural Plans*, Z32.9.

The Standard Z32.3, sold at a cost of 40 cents, supersedes the former AIEE pamphlet 17g2, published in 1934. The new standard for "Telephone, Telegraph, and Radio Use," Z32.5, sold at a cost of 30 cents, supersedes the two former AIEE pamphlets 17g3 and 17g6, issued in 1934 and 1929, respectively. The third symbol standard, number Z32.9, sold at a cost of 20 cents, supersedes the AIEE standard 42 issued in 1923 entitled "Symbols for Electrical Equipment of Buildings."

Copies of all three symbol standards can be obtained from AIEE headquarters, 33 West 39th Street, New York, N. Y., at the prices listed above with usual 50 per cent discount to AIEE members on single copies.

Standard on Neutral Grounding Devices to Be Revised

AIEE Standard 32, Neutral Grounding Devices, is to be revised soon, according to J. E. Clem, chairman of the subcommittee on fault-current-limiting devices which is in charge of the preparation of this standard. Comments and suggestions pertinent to the proposed revision of the standard should be sent directly to Mr. Clem. The standard was issued in preliminary form in June 1942 with the expectation that it would be given trial use for a period of about one year, after which it would be revised in accordance with comments and suggestions received.

PERSONAL . . .

A. R. Robison (A '12, F '41) formerly of the firm of Sanderson and Porter, Engineers and Constructors, Charlotte, N. C., has been appointed manager of the Middletown division of the Cincinnati (Ohio) Gas and Electric Company. Mr. Robison, who graduated from the University of Minnesota in 1909, commenced his engineering career as a foreman and electrical engineer

for the Montana Power Company, Great Falls, from 1910 to 1915. He spent the years from 1918 to 1926 as construction superintendent in Pennsylvania, Alabama, Florida, West Virginia, and Wyoming, for the J. G. White Engineering Corporation, New York, N. Y. He was vice-president and general manager of the Central Ohio Light and Power Company, Findlay, from 1929 to 1938. For one term (1938-39) he served as city manager of Celina, Ohio. From 1939 to 1942 he was chief engineer on the Public Utilities Commission of Ohio.

L. G. Woodford (M '31, F '42) formerly chief engineer of the operations and engineering department, American Telephone and Telegraph Company, New York, N. Y., has been appointed general manager of the long lines department. As clerk and appraisal engineer he was first associated with the Iowa Telephone Company, Des Moines, from 1911 to 1914. He continued as appraisal engineer with the Northwestern Group of Bell Telephone Companies, Des Moines, Iowa, until 1920 when he was made engineer of costs and practices. In 1923 he was transferred to the American Telephone and Telegraph Company, as an engineer in the department of operations and engineering. He remained in that department becoming plant inventory and costs engineer in 1927, plant extension engineer in 1933, operating results engineer in 1937, and plant operation engineer in 1939. In 1940 he was appointed assistant vice-president and chief engineer in 1941.

John Bankus (A '20) formerly assistant chief engineer, Portland (Oreg.) General Electric Company, has been appointed chief engineer. Graduating from the University of California in 1915 he did heavy installation work for the Crown Willamette Paper Company, West Linn, Oreg., and engineering for the Pacific Mills, Ltd., Ocean Falls, B. C., until 1918. As an electrician he served with the United States Navy for one year. During 1919 he was an electrician with the Northwestern Electric Company, Portland, Oreg. From 1920 to 1922 he was employed by the Portland (Oreg.) Railway, Light, and Power Company as an electrical engineer. He joined the General Electric company in 1923 as an assistant engineer, later becoming electrical engineer. As assistant chief engineer Mr. Bankus has directed the building of transmission lines, new substations, steam and hydroelectric plants.

C. R. R. Harris (A '19) vice-president of The Kerite Insulated Wire and Cable Company, Inc., has been elected president of that company. Born in Randolph County, Ind., in 1882, he entered the engineering inspection department of the Western Electric Company, Chicago, Ill., in 1909. In 1909 he was transferred to the same department at New York, N. Y. He joined the Western Union Telegraph Company, New York, N. Y., in 1910, where

he organized an inspection department and prepared material specifications. From 1913 to 1917 he engaged in special studies for the company. He became associated with the Kerite company in 1917 as engineer in charge of all technical problems. In 1927 he became vice-president and general manager of the corporation.

D. C. Hierath (A '35) radio and television specialist, industrial department, General Electric Company, New York, N. Y., is one of the 18 electronic specialists appointed by the General Electric Company with responsibility for all industrial electronic applications in their territories. Others so appointed are: **A. J. Moore** (A '38) sales engineer in the industrial department, Boston, Mass.; **J. A. Setter** (A '41) sales engineer and industrial control specialist, Denver, Colo.; **I. F. Conrad** (A '31) of the sales department, St. Louis, Mo.; **L. R. Elder** (A '10, M '26) of the sales department, Portland, Oreg.; **Burnham Cogswell** (A '22, M '34) field engineer, Buffalo, N. Y.; and **L. F. Stone** (A '23, M '30) local office engineer, Newark, N. J.

R. M. Smith (A '35) formerly assistant chief engineer, Roller-Smith Company, Bethlehem, Pa., has been appointed chief engineer. Before joining the Roller-Smith Company in 1942, Mr. Smith, a graduate of the University of Washington, had been manager of the engineering department of the wiring and device division, Bryant Electric Company, Bridgeport, Conn. From 1925 to 1941 he was section engineer with the Westinghouse Electric and Manufacturing Company, Newark, N. J.

J. R. Weeks (A '40) supervisor of the instrument laboratory, quality control division, Westinghouse Electric and Manufacturing Company, Mansfield, Ohio, has been awarded the *Aero Digest* prize of a \$100 war bond for the best wartime production short cut. Mr. Weeks designed an inspection-device optical system which increases the production rate of a vital airplane part by 20 per cent and decreases the cost by one tenth.

J. W. Cable (A '38) sales engineer, Induction Heating Corporation, New York, N. Y., has been made general sales manager. After graduating from Rensselaer Polytechnic Institute in 1933, Mr. Cable joined the Consolidated Edison Company of New York (N. Y.), Inc. He remained with that company as tester and junior engineer until 1941 when he entered the employ of the Induction Heating company.

J. J. Pilliod (M '17, F '34) formerly general manager of the long lines department of the American Telephone and Telegraph Company, New York, N. Y., has been made assistant chief engineer of the operations and engineering department. Mr. Pilliod had been engineer in charge of the long lines department since 1920. In 1941 he was appointed general manager.

M. F. Skinker (A '22, F '34) chief of the selenium development laboratory, Federal Telephone and Radio Corporation, East Newark, N. J., has been appointed manager of the rectifier department. For a fuller biography of Dr. Skinker see the November 1942 issue of *Electrical Engineering*, page 577.

J. B. Klumpp (A '02, F '13) consulting engineer of Philadelphia, Pa., has been elected a director of the American Meter Company, Philadelphia, Pa.

F. F. Fowle (A '12, M '12) consulting engineer of Chicago, Ill., has been elected president of the Illinois Engineering Council.

OBITUARY

Earle Raymond Hedrick (M '25) retired provost, vice-president, and professor of mathematics at the University of California, Los Angeles, died February 3, 1943. He was born September 27, 1876, at Union City, Ind., and received the degrees of bachelor of arts from the University of Michigan in 1896, master of arts from Harvard University in 1898, and doctor of philosophy from the University of Goettingen in 1901. The University of Michigan conferred the honorary degree of doctor of science upon him in 1936, and the University of Missouri, the honorary degree of doctor of laws in 1939. He was instructor of mathematics at the Sheffield Scientific School of Yale University, New Haven, Conn., from 1901 to 1903. In 1903 he was appointed professor of mathematics at the University of Missouri, Columbia, where he remained until 1924. As professor of mathematics he joined the faculty of the University of California in 1924. In 1937 he was made provost and vice-president. He retired in June 1942 and joined the staff of Brown University, Providence, R. I., to assist in the production of the new *Quarterly of Applied Mathematics*. In 1919 he was director of mathematics for the Army Educational Corps of the American Expeditionary Force. Since 1921 he had been editor in chief of the American Mathematical Society *Bulletin*. He was president of the American Mathematical Society for 1929-30, and of the Mathematical Association of America in 1916. His other society affiliations include membership in the American Association for the Advancement of Science, American Society of Mechanical Engineers, the Société Mathématique de France, the Circolo Matematico Di Palermo, the Society for the Promotion of Engineering Education, the American Association of University Professors, Deutsche Mathematiker Vereinigung, and Phi Beta Kappa. In 1932 he was decorated Officier d'Academie (France). He wrote several textbooks on mathematics and published articles in various periodicals.

Thomas Russel Millar (A '08, M '13) assistant engineer, Hydro-Electric Power Commission of Ontario, Toronto, died

March 2, 1943. Born July 30, 1884, at Kingston, Ont., he received the degree of bachelor of science in engineering from Queens University. He entered the test course of the General Electric Company, Lynn, Mass., in 1906. During 1908 he served as engineer on construction with the J. G. White Construction Company, New York, N. Y., and substation operator for the Buffalo, Lockport, and Rochester Railway, Brockport, N. Y. In 1909 he was employed in the engineering department of the Ontario Power Company, Niagara Falls, and joined the engineering staff of the Shawinigan Water and Power Company, Quebec, Que., in 1910. From 1911 to 1913 he was field engineer for the Midland Construction Company, Toronto. He became assistant engineer with the Electric Power Company, Toronto, in 1913 and was chief engineer in 1916, when the company's properties were purchased by the province of Ontario. Mr. Millar remained on the electrical engineering department staff when the Hydro-Electric Power Commission assumed control. In 1939 he was appointed engineer in charge of the station section of the electrical engineering department. He was also a member of the Professional Engineers Association of Ontario.

Willard E. Boileau (A '94, M '96) consulting engineer, Bath, N. Y., died August 3, 1942. Born September 8, 1865, at Bath, he commenced his career as a construction engineer and plant manager with the Thomson Houston Electric Company, Seneca Falls, N. Y., in 1886. He remained with that company and its successor, the General Electric Company until 1905 in various capacities. In 1887 he was transferred to Lynn, Mass., where he was enrolled in a training course. Subsequently until 1894 he was engaged in building plants throughout Georgia, at Brunswick, Macon, Columbus, and Rome. From 1894 to 1905 he was superintendent of the Brush Electric Light and Power Company, Columbus, Ga. In addition he acted as consultant to several smaller plants in the region. From 1905 to 1907 he worked as mechanical designing engineer with the New York (N. Y.) Westchester and Boston Railway. He became general manager of the Chattanooga (Tenn.) Railway and Light Company in 1907 and of the Scranton (Pa.) Railway Company in 1914. From 1920 to 1923 he was general manager of the Peoples Railway Company, Dayton, Ohio. In 1924 he established his own consulting engineering firm at Bath. During World War I he served on the Public Safety Committee of Pennsylvania.

Rodman Ernest Jerauld (A '21) assistant to the manager, General Electric Company, Los Angeles, Calif., died on February 25, 1943. He was born March 30, 1880, in Providence, R. I., and was graduated from Throop Polytechnic Institute in 1902. He started work as a draftsman with the Union

Oil Tool Company, Los Angeles, that year. In 1903 he did surveying for the Pacific Electric Railway Company, Los Angeles, and was plant operator for the Riverside Power Company, Los Angeles, during 1904. He joined the General Electric Company first in 1905, when he entered the testing department of the Lynn (Mass.) Works. In 1907 he was transferred to a sales position in the company's Salt Lake City (Utah) office. During 1909 and 1910 he was chief electrician for the Great Northern Development Company, Alaska. Returning to the General Electric Company in 1910, he remained at the Salt Lake City office until 1912. He was placed in charge of the company's Boise (Idaho) office from 1912 to 1915, when he returned to Salt Lake City. He was made resident agent at Phoenix, Ariz., in 1924 and in 1925 became manager. In 1939 he was transferred to Los Angeles as assistant to the manager.

Charles O. Falkenwald (A '40) director of the examining division of the Rural Electrification Administration died March 25, 1943. He was born January 13, 1902, in Baltimore, Md., and began his career there in 1920 as electrical engineer for the Electrical Construction Company. In 1923 he organized the County Electric Company, Baltimore, which he operated until 1931. This company specialized in rural electrification projects. From 1929 to 1931 he also organized and operated the County Gas and Electric Company, Baltimore, which chiefly engaged in making surveys for different gas-pipe-line companies. In 1931 he organized and became a partner in the Oil Burners Distributing Company, Baltimore. He continued in this firm until he joined the Rural Electrification Administration in 1935 as field representative in the engineering division. He was made project adviser in 1936 and special field representative for the administrator in 1937. Later that year he was named acting director of the examining division. In 1938 he was appointed director.

Frank Bourne (A '91, M '92) consulting engineer of London, England, died in February 1943. Born May 15, 1859, at Ash, Kent, England, he first practiced engineering as an apprentice mechanical engineer in the shops of Foster and Sons, Preston, Lancashire, England, from 1876 to 1881. He worked as engineer for the shipbuilding firm of J. Renmi and Company until 1885, when he joined the Edison Works, New York, N. Y. After a training period in various departments, he took charge of repair work throughout New York City. Later he was made inspector on power plants. During 1889 he was associated with E. J. Birdsall, Consulting Engineer, New York, N. Y. In 1890 he became electrical engineer with the Field Engineering Company, New York, N. Y. Shortly before 1900 he established his own consulting engineering firm. A few years later he returned to England where he continued in the same field.

Richard de Wolfe Brixey (A '08) president, treasurer, and director of the Kerite Insulated Wire and Cable Company, New York, N. Y., died March 14, 1943. Born in Seymour, Conn., September 22, 1880, he received the degree of bachelor of philosophy from the Sheffield Scientific School of Yale University in 1902. Immediately assuming the duties of general manager of the Kerite company, he commenced a lifetime affiliation with that firm. In 1909 he was named president. He was also a member of the Army Ordnance Association, the American Chemical Society, the American Society for Testing Materials, the American Railway Engineering Association, and the Association of American Railroads.

John Albert Johnson (A '40) assistant mechanical and electrical engineer, Chicago (Ill.) Bridge and Iron Company, died November 22, 1942. Mr. Johnson was born October 13, 1909, in Lisbon, N. Dak., and was graduated from the University of Minnesota in 1935. He was employed by the John Deere Tractor Company, Waterloo, Iowa, from 1935 to 1937 on experimental laboratory testing and on tool design in the methods department. In 1937 he joined the Chicago Bridge and Iron Company. He was a junior member of the American Society of Mechanical Engineers and a member of the American Welding Society.

John Happy (A '40) engineer in the research and statistical department of the Cleveland (Ohio) Electric Illuminating Company, died February 10, 1943. Born February 20, 1914, in Cleveland, Ohio, he received the degree of bachelor of science in electrical engineering from the Case School of Applied Science in 1939. He was employed by the Ohio Public Service Company, Cleveland, as a junior engineer, during 1939. In 1940 he became research engineer for the Swartwout Company, Cleveland, and joined the Electric Illuminating company in 1941.

Harvey Ingo Nitz (A '41) lieutenant in the United States Army, died December 8, 1942. Born May 5, 1918, at Evanston, Ill., he was graduated from the University of Illinois with the degree of bachelor of science in mechanical engineering in 1940. Before entering military service he was employed by the General Electric Company, Schenectady, N. Y., from July to November 1940, as a test engineer. He was a junior member of the American Society of Mechanical Engineers.

John C. Lee (A '90) retired engineer of Wellesley, Mass., died on December 16, 1942. He was born December 2, 1864, and studied at Dresden, Germany, in 1888. From 1889 to 1907 he was associated with the American Telephone and Telegraph Company, Boston, Mass., as a chemist and electrician. He retired in 1907 to carry on independent research and invention. He held patents on a lens-grinding machine and a telescope.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners, at its meeting on April 22, 1943, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Baltzly, C. C., general superintendent, Philadelphia Electric Company, Philadelphia, Pa.
Chubbuck, L. B., assistant chief engineer, Canadian Westinghouse Company, Ltd., Hamilton, Ont., Canada.
Early, R. N., electrical engineer, Electric Machinery Manufacturing Company, Minneapolis, Minn.
Hessler, V. P., professor and head, department of electrical engineering, University of Kansas, Lawrence, Kans.
Hull, A. H., electrical engineer, Hydroelectric Power Commission of Ontario, Toronto, Ont., Canada.
Logan, H. L., consulting engineer, Holophane Company, Inc., New York, N. Y.
Rode, N. F., professor of electrical engineering, Texas A. & M. College, College Station, Tex.
Swanstrom, F. N., chief of electrical design, Electric Machinery Manufacturing Company, Minneapolis, Minn.
Tarboux, J. G., professor in charge, electrical engineering department, University of Tennessee, Knoxville, Tenn.
Thaxton, G. W., chief, design and construction division, Rural Electrification Administration, Washington, D. C.
Traver, O. C., patent engineer, General Electric Company, Philadelphia, Pa.
Wood, E. M., planning engineer, Hydroelectric Power Commission of Ontario, Toronto, Ont., Canada.
12 to grade of Fellow

To Grade of Member

Blatz, I. H., electrical engineer, Kollsman Institute Division, Square D Company, Woodside, N. Y.
Brooks, Eric, engineer, North Electric Manufacturing Company, Galion, Ohio.
Credle, A. B., assistant professor of electrical engineering, Cornell University, Ithaca, N. Y.
Davis, H. L., engineer, Philadelphia Electric Company, Philadelphia, Pa.
Denbin, A. G., assistant superintendent of power, The Baltimore Transit Company, Baltimore, Md.
Edwards, L. C., assistant engineer, Pacific Gas and Electric Company, Emeryville, Calif.
Ernst, M. L., estimating and operating engineer, Detroit Edison Company, Detroit, Mich.
Fiske, C. S., assistant to vice-president, Consolidated Gas, Electric Light, and Power Company, Baltimore, Md.
Jackson, H. H., specification engineer, Detroit Edison Company, Detroit, Mich.
Jenkins, A. C., transportation research engineer, Railroad Commission, State of California, San Francisco, Calif.
Klaus, C. E., application engineer, Westinghouse Electric and Manufacturing Company, Portland, Oreg.
Krantz, C. H., equipment development and test engineer, Douglas Aircraft Company, Santa Monica, Calif.
Lindsey, J. W., electrical engineer, Willamette Iron and Steel Corporation, Portland, Oreg.
Mason, W. S., plant engineer, Aberdeen Proving Ground, Md.
McCartin, J. W., engineer, Long Island Lighting Company, Mineola, N. Y.
McLean, True, assistant professor of electrical engineering, Cornell University, Ithaca, N. Y.
Mitchell, W. D., engineer, American Telephone and Telegraph Company, New York, N. Y.
Narbutovskih, Paul, engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Olson, S. G., district superintendent, Pacific Gas and Electric Company, San Francisco, Calif.
Pickles, Sidney, radio engineer, Federal Telephone and Radio Laboratories, New York, N. Y.
Reed, W. H., electrical engineer, Todd Hoboken Dry Docks, Inc., Hoboken, N. J.
Rietow, L. A., purchasing agent and service engineer, Control Corporation, Minneapolis, Minn.
Robertson, W. D., district manager, Canadian General Electric Company, Ltd., Vancouver, B. C., Canada.
Schiffreen, C. S., engineer, Philadelphia Electric Company, Philadelphia, Pa.
Schuknecht, R. C., senior engineer, United States Army Engineers, Portland, Oreg.
Solomon, D. L., Federal Telephone and Radio Corporation, East Newark, N. J.
Sovik, R. A., sales engineer, Copperweld Steel Company, New York, N. Y.
Sowers, J. E., engineer, Bethlehem Steel Corporation, Lackawanna, N. Y.
Thomas, W. A., electrical engineer, E. I. du Pont de Nemours and Company, Inc., Wilmington, Del.
Winter, W. L., application engineer, Westinghouse Electric and Manufacturing Company, San Francisco, Calif.

30 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical District. Any member objecting to the election of any of these candidates should inform the national secretary before May 31, 1943, or July 31, 1943, if the applicant resides outside of the United States or Canada.

To Grade of Member

Barnes, E. C. (Member re-election), P. & P.R.R., Seattle, Wash.
 Baxter, W. J. (Member re-election), Gen. Elec. Co., Cleveland, O.
 Boddy, J. G., Basic Magnesium Inc., Las Vegas, Nev.
 Brown, Dr. W. S. (Member re-election), Gen. Cable Corp., Perth Amboy, N. J.
 Burnett, G. F., Lockheed Aircraft Corp., Burbank, Cal.
 Carroll, R. S. (Member re-election), Portland Gen. Elec. Co., Portland, Ore.
 Castner, R. F., W. E. & M. Co., Des Moines, Iowa.
 Crago, P. H. (Member re-election), Union Switch & Signal Co., Swissvale, Pa.
 Currie, F. L. (Member re-election), Western Union Tel. Co., New York, N. Y.
 Gemmell, R. W., W. E. & M. Co., E. Pittsburgh, Pa.
 Gentry, W. A. (Member re-election), W.P.B., Washington, D. C.
 Greibach, E. H., Sonotone Corp., Elmsford, N. Y.
 Groden, E., U. S. Engr. Office, Boston, Mass.
 Groh, G. H. (Member re-election), Cent. Arizona L. & P. Co., Phoenix, Ariz.
 Harlow, J. H., Phila. Elec. Co., Philadelphia, Pa.
 Hays, E. M., Dravo Corp., Neville Island, Pa.
 Kuhl, F. P. (Member re-election), Con. Edison Co., New York, N. Y.
 Lang, C. H., Gen. Elec. Co., Schenectady, N. Y.
 Lips, J. G. (Member re-election), B. F. Goodrich Co., Akron, O.
 Maxian, J., Jr., No. Amer. Aviation, Inc., Inglewood, Cal.
 Mercedith, F. M., Industrial Power Equipment Co., Baltimore, Md.
 Metcalf, D. J. W. (Member re-election), Mott Elec. Ltd., Vancouver, B. C., Can.
 Polydoroff, W. J., Chicago, Ill.
 Ramsey, G. F., Farnsteel Metallurgical Corp., N. Chicago, Ill.
 Robinson, J. W. (Member re-election), Western Union Tel. Co., New York, N. Y.
 Sanders, H. M. (Member re-election), Austin Co., Cleveland, O.
 Siefkin, E. R., Lockheed Air Terminal, Burbank, Cal.
 Silverman, H. H., Beach Elec. Co., Newark, N. J.
 Smith, I. R. (Member re-election), W. E. & M. Co., E. Pittsburgh, Pa.
 Smith, R. A., Northrop Aircraft Inc., Hawthorne, Cal.
 Smith, T. A. (Member re-election), Glasgow, N. Scotland.
 Wolff, S. S. (Member re-election), Century Elec. Co., St. Louis, Mo.
 Wood, G. M. (Member re-election), W. E. & M. Co., E. Pittsburgh, Pa.

33 to grade of Member

To Grade of Associate

United States and Canada

1. NORTH EASTERN

Aidala, J. H., U. S. Navy Yard, Boston, Mass.
 Crane, E. G., Jr., Gen. Elec. Co., Lynn, Mass.
 Davidson, G. R., Bethlehem Steel Co., Lackawanna, N. Y.
 Duncan, M. R., Gen. Elec. Co., Lynn, Mass.
 Jones, E. M., Gen. Elec. Co., Syracuse, N. Y.
 Kenefake, E. W., Gen. Elec. Co., Schenectady, N. Y.
 Nason, F. L. (Associate re-election), W. E. & M. Co., Boston, Mass.
 Peters, P. H., Gen. Elec. Co., Schenectady, N. Y.
 Phillips, C. L., Gen. Elec. Co., Schenectady, N. Y.
 Shaul, L. K., Gen. Elec. Co., Schenectady, N. Y.
 Walker, H. S., Gen. Elec. Co., Syracuse, N. Y.
 Washburn, I., U.S.N.R., M.I.T., Cambridge, Mass.
 Watzich, J., Jr., Gen. Elec. Co., Schenectady, N. Y.

2. MIDDLE EASTERN

Adcock, H. V., Line Material Co., Zanesville, O.
 Andrews, G. E., U. S. Army Res., Cleveland, O.
 Antilla, C. R., Navy Dept., Washington, D. C.
 Baker, L. R., N. Y. Shipbuilding Corp., Camden, N. J.
 Bartholomew, W. R., Master Elec. Co., Dayton, O.
 Bates, E. J. (Associate re-election), Natl. Cash Register Co., Dayton, O.
 Belding, L. S., Elec. Service Supplies Co., Philadelphia, Pa.
 Brader, D. W., Gen. Elec. Co., Philadelphia, Pa.
 Brumbaugh, K. D. (Associate re-election), National Advisory Comm. for Aeronautics, Cleveland, O.
 Carolus, J. B., Leeds & Northrup Co., Philadelphia, Pa.
 Colosi, A., Dravo Corp., Neville Island, Pa.
 Daussman, G. F., U. S. Navy Dept., Neville Island, Pa.
 Dawirs, H., W. E. & M. Co., Sharon, Pa.
 Dirksen, Major A. D., U. S. Army, Dayton, O.
 Dodson, V. E., Gen. Elec. Co., Los Angeles, Cal.
 Dorsey, J. C., Phila. Elec. Co., Morton, Pa.
 Edwards, F. G., Stone & Webster Engg. Corp., Williamsport, Pa.
 Eisele, W. A., Ensign, U.S.N., Washington, D. C.

Elverson, W. H., Gulf Oil Corp., Philadelphia, Pa.
 Finison, H. J., War Dept., Wright Field, Dayton, O.
 Freeland, M. W., Bur. of Ships, Navy Dept., Washington, D. C.
 Gray, D., W. E. & M. Co., E. Pittsburgh, Pa.
 Hentschel, H. F., Gen. Elec. Co., Philadelphia, Pa.
 Hoefler, R. H., National Cash Register Co., Dayton, O.
 Hubbard, J. C., Con. Gas & Elec. L. & P. Co., Baltimore, Md.
 Johnson, F. F., Delco Products, Dayton, O.
 Jordan, C. L., Dravo Corp., Neville Island, Pa.
 Karcher, E. R., John Hopkins Univ., Silver Spring, Md.
 Kirschbaum, H. S., W. E. & M. Co., E. Pittsburgh, Pa.
 Krewson, W. V., City Ry. Co., Dayton, O.
 Leydorf, G. E., Univ. of Toledo, Toledo, O.
 Lundberg, J. E., U. S. Army Signal Corps, Philadelphia, Pa.
 Macdonald, C. L., Office Lend Lease Adm., Washington, D. C.
 Magruder, J. McE., Cons. Gas & Elec. Co., Baltimore, Md.
 Mahoney, D. T., W. E. & M. Co., Sharon, Pa.
 Moreton, S. D., Gen. Elec. Co., Phila., Pa.
 Pickering, D. M., Master Elec. Co., Dayton, O.
 Poliquin, P. P., Frigidaire Pl. Co., Moraine, O.
 Peek, J. T., Cleveland Elec. Ill. Co., Cleveland, O.
 Rood, J. C., Air Service Command, Fairfield, O.
 Sander, L. K., Nat'l. Cash Register Co., Dayton, O.
 Schneider, E. H., Jr., Locke Insulator Corp., Baltimore, Md.
 Slingluff, B. F., Potomac Elec. Power Co., Washington, D. C.
 Smucker, E. J., Naval Aircraft Factory, Philadelphia, Pa.
 Stijacich, G. B., Gen. Elec. Co., Erie, Pa.
 Sturgis, B. K., I-T-E Circuit Breaker Co., Philadelphia, Pa.
 Tashjian, G. K., Cincinnati Gas & Elec. Co., Cincinnati, O.
 Timmerman, J. W., Jr., Gen. Elec. Co., Philadelphia, Pa.
 Trant, J. L. (Associate re-election), Brown Brockmeyer Co., Dayton, O.
 Tusin, A. S. (Associate re-election), Reliance Elec. & Engg. Co., Cleveland, O.
 Walcutt, J. L., Anacostia Sta., Washington, D. C.
 Walton, A. K. (Associate re-election), W. E. & M. Co., E. Pittsburgh, Pa.
 Wendelken, W., W. E. & M. Co., E. Pittsburgh, Pa.
 Whiddett, J. C., Automatic Temp. Control Co., Philadelphia, Pa.
 Wieland, E. S., Aircraft Radio Lab., Wright Field, O.
 Willard, R. S., Jr., R.C.A. Service Co., Camden, N. J.
 Wilson, C. W., Atmospheric Nitrogen Corp., Ironton, O.

3. NEW YORK CITY

Aguire, R. P. C., Ebasco International Corp., New York, N. Y.
 Barnes, T. D., W. E. & M. Co., Newark, N. J.
 Bastian, A. L., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
 Bouie, W., Camp Evans Signal Lab., Belmar, N. J.
 Campbell, J. A., "Electrical Manufacturing," New York, N. Y.
 Costic, A. B., D. L. & W. R.R. Co., Hoboken, N. J.
 Crofton, T. J., H. B. Sherman Mfg. Co., New York, N. Y.
 Cuciti, A., Dept. of Public Works, City of N. Y., New York, N. Y.
 Day, E. C. (Associate re-election), Signal Corps, Camp Evans, Belmar, N. J.
 Doyle, J. J., Jr., Staten Island Edison Corp., Staten Island, N. Y.
 Hartmann, Z. (Associate re-election), Belmont Elec. Co., New York, N. Y.
 Janzen, C. F., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
 Kaplan, M., Fed. Tel. & Rad. Lab., 67 Broad St., N.Y.C.
 Kirshner, D. R., Eatontown Signal Lab., Eatontown, N. J.
 Librizzi, F. P., U. S. Naval Res., Bur. of Ord., Newark, N. J.
 Licht, J. A., Rogers Diesel & Aircraft Corp., Bronx, N. Y.
 Lomholt, C., Bendix Aviation Corp., Bendix, N. J.
 McKean, A. L., Phelps Dodge Copper Products Corp., Yonkers, N. Y.
 McMahon, J. T., Signal Corps Zone, Newark, N. J.
 Paleschuck, M. H., Coll. City of N. Y., New York, N. Y.
 Pollock, M. D., Republic Steel Corp., Brooklyn, N. Y.
 Sansone, T. D., Ward Leonard Elec. Co., New York, N. Y.
 Schneck, L. H., Int'l. Diesel Elec. Co., Long Island City, N. Y.
 Sleys, J. T., Ward Leonard Elec. Mfg. Co., New York, N. Y.
 Spikula, R. W., Western Elec. Co., S. Kearny, N. J.
 Storm, J. E., Frederic R. Harris Inc., New York, N. Y.
 Tizian, S. L. (Associate re-election), H. A. Frazer, Inc., New York, N. Y.
 Woodruff, H. S., Con. Ed. Co., New York, N. Y.

4. SOUTHERN

Owen, A. G., E. I. duPont, Martinsville, Va.
 Peeples, H. C., Tenn. Valley Authority, Chattanooga, Tenn.
 Spalding, R. D., Louisville Gas & Elec. Co., Louisville, Ky.
 Wages, W. L., Tennessee Valley Authority, Chattanooga, Tenn.

5. GREAT LAKES

Chayka, F. J., Gen. Elec. Co., Fort Wayne, Ind.
 Frank, J. M., Louis Allis Co., Milwaukee, Wis.
 Hemman, R. J. E., Ill. Inst. of Tech. Chicago, Ill.
 Jones, R. W. (Associate re-election), Consumers Power Co., Jackson, Mich.
 Leonard, L. V., Public Service Co. of Ind., Inc., Indianapolis, Ind.
 Myers, M. D., The Austin Co., Midland, Mich.
 Riezman, S., Univ. of Mich., Ann Arbor, Mich.
 Stephens, W. T. (Associate re-election), W. E. & M. Co., Madison, Wis.
 Weber, H. A., Gen. Motors Co., Anderson, Ind.
 Williksen, A., James Stewart & Co., Chicago, Ill.
 Wise, M., American Steel & Wire Co., Joliet, Ill.
 Yang, I., Louis Allis Co., Milwaukee, Wis.
 Youngblood, J., Detroit Edison Co., Detroit, Mich.

6. NORTH CENTRAL

Reno, H., Hathaway Instrument Co., Denver, Colo.

7. SOUTH WEST

Agrelus, P. W., Shelley Elec. Co., Wichita, Kans.
 Auld, N. C., Okla. Gas & Elec. Shawnee, Okla.
 Blackford, W. R., Associated Architects & Engrs. Oklahoma City, Okla.
 Gransberry, I. J., Kans. G. & E. Co., Wichita, Kans.
 Hantla, O. R., Kansas Gas & Elec. Co., Wichita, Kans.
 Herring, H. C., Southwestern Bell Tel. Co., Beaumont, Tex.
 Howdeshell, A. D., Gen. Elec. Co., Houston, Tex.
 Lovell, H. J., WKY Radiophone Co., Oklahoma City, Okla.
 Saxon, A. N., Graybar Elec. Co., Dallas, Tex.
 Small, F. R., Southwestern Bell Tel. Co., St. Louis, Mo.
 Thomas, M. W., KOMA Inc., Oklahoma City, Okla.
 Vande Steeg, G. J., Southwestern Bell Tel. Co., St. Louis, Mo.
 Watrous, J. F., W. E. & M. Co., Oklahoma City, Okla.

8. PACIFIC

Beers, K. H., Aluminum Co. of America, Torrance, Cal.
 Calvin, E. F., Vega Aircraft Corp., Hollywood, Cal.
 Carter, J. A., Douglas Aircraft Co., El Segundo, Cal.
 Collard, T. B., So. Cal. Tel. Co., Los Angeles, Cal.
 Cunningham, C. E., Farnham & Cunningham, Los Angeles, Cal.
 Duyan, P., Jr., Douglas Aircraft Co., Santa Monica, Cal.
 Farhat, A. A., Douglas Aircraft Co., Santa Monica, Cal.
 Harris, T., Owner, H. S. Tittle Co., San Francisco, Cal.
 Johnson, F. V., Leeds, Hill, Barnard & Jewett, Los Angeles, Cal.
 Kempf, K. G., Thomas & Betts Co., Los Angeles, Cal.
 Mayer, W. H., Jr., Ames Aero Lab., Moffett Field, Cal.
 McCabe, C. F., Cons. Aircraft Corp., San Diego, Cal.
 McCormack, H. P., U. S. Navy, Bethlehem Steel Co., San Francisco, Cal.
 Miller, Owens, Condon & Young, Inc., Los Angeles, Cal.
 Moore, L. L., Douglas Aircraft Co., Santa Monica, Cal.
 Owen, T. B., Douglas Aircraft Co., Santa Monica, Cal.
 Padgett, L. K., Kaiser Cargo Inc., Oakland, Cal.
 Reed, R. W., Pacific Bridge Co., San Diego, Cal.
 Rempt, H. F., Lockheed Aircraft Corp., Burbank, Cal.
 Schuyler, D. W., Douglas Aircraft Co., W. Los Angeles, Cal.
 Tucker, V. L., Douglas Aircraft Co., El Segundo, Cal.
 Vickrey, J. D., Aluminum Co. of America, Torrance, Cal.
 Weatherford, D. E., U. S. Maritime Comm., Oakland, Cal.
 Williams, S. H., No. Amer. Aviation Corp., Inglewood, Cal.

9. NORTH WEST

Nelson, J. M. (Associate re-election), Seattle Light- ing Dept., Seattle, Wash.
 Rasmussen, G. S., Puget Sound Navy Yard, Seattle, Wash.
 White, R. N., Bonneville Power Adm., Vancouver, Wash.

10. CANADA

Doyle, P. M., Pontiac Ow. & Dev. Co., Ft. Coulonge, Que., Can.
 Grinski, G., Northern Elec. Co., Montreal, Que., Can.
 Hultgren, W., West Coast Shipbuilders Ltd., Vancouver, B. C., Can.
 Hume, H. F., Hume & Rumble Ltd., Vancouver, B. C. Can.
 King, E. W., Can. Gen. Elec. Co., Peterboro, Ont., Can.
 Rich, R., R.C.N.V.R., H.M.C. Dockyard, Esquimalt, Can.

Elsewhere

Morrison, W. E., Westinghouse Elec. Int'l. Co., Santiago, Chile, S. A.
 O'Doherty, J. J., Electricity Supply Bd., Dublin, Ireland.
 Saner, J., Johnson & Phillips Ltd., London, England.
 Winther, C., Westinghouse Elec. Co. of S. A. Ltd., Johannesburg, S. A.
 Young, W. W., Dept. of Science & Industrial Research, Christchurch, New Zealand.

Total to grade of Associate
 United States and Canada, 162
 Elsewhere, 5

OF CURRENT INTEREST

New Agency Provides Central Source of Critical Electronic Parts

The Electronic Research Supply Agency, whose purpose is to supply research men with the electronic components vital to their work, has been established recently by the Defense Supplies Corporation at the request of the Armed Services.

The new agency aims to provide a central source of supply of critical electronic components not readily available in commercial channels for laboratories working on radio problems for the Army or Navy. This should minimize the time and expense that laboratories of universities, industrial companies, and the government have been devoting to finding the unusual parts which they hitherto have had to collect individually.

The agency, which expects to establish offices and stockrooms in New York, is operated without profit and managed by an executive committee on which the Army, Navy, and other government agencies are represented. Laboratories are urged to continue to use available sources for their usual needs and to call upon the agency only as a last resort.

New Communication Aid Transmits Several Messages Simultaneously

The "Spiral-4," a carrier communication system permitting several long-distance messages to be transmitted simultaneously over a set of conductors, has recently been made available for the war program by Western Electric Company and Bell Telephone Laboratories.

The Spiral-4 system provides three telephone and four telegraph circuits over a single rubber-covered cable about the thickness of a fat lead pencil. The cable contains four spiralling wires and is made in quarter-mile lengths, the ends of which are fitted with weather-proof connectors. Each length may be snapped to a companion section as rapidly as the cable can be payed off a moving Army truck. With intermediate amplifiers spaced along the way to compensate for loss in the strength of the current, distances up to 150 miles may be spanned.

Corps of Engineers to Recruit 9,000 Specialists a Month

The United States Corps of Engineers has been authorized to undertake a recruiting program which will assure civilian-trained specialists, assignment in engineer troop units. With the abatement of the domestic army emergency construction program, technicians hitherto deferred will

be coming up for induction into the armed forces. From their ranks the Corps of Engineers hopes to recruit 9,000 specialists a month. The nearest United States Army engineers office will pass upon the qualifications of the volunteers and will provide a letter, earmarking them for the engineers, to be presented at their respective induction stations.

In instituting this program, the Corps of Engineers is anticipating a growing need for trained men to aid in construction abroad and in moving constantly increasing numbers of troops to foreign battlefronts.

Those inducted into the Engineers under the new plan will have the same opportunity to secure commissions through the Engineer Officer Candidate School as other enlisted men. However their previous training should allow them to advance more rapidly than the normal candidate.

Bureau of Manpower Utilization to Be in Operation by Midsummer

The War Manpower Commission's Bureau of Manpower Utilization is expected to be in full operation in almost every industrialized center of the United States by midsummer, according to Paul V. McNutt, chairman.

Operation of the Bureau would be completely decentralized with from 6 to 23 utilization consultants having experience in plant management attached to the staff of each regional man-power director. There would be eventually 200 consultants in the field, not more than six or eight with headquarters in Washington. Mr. McNutt stated that more than 50 consultants are already in the job, four regions having their full force and all regions having some consultants at present.

Emphasizing the voluntary nature of the program, Mr. McNutt said that the consultant's job is not to "inspect" but to provide help and advice to firms which request it. The consultants are trained in the use of manning tables, replacement schedules and in occupational and worker analysis techniques, and can advise employers how to adapt these tools to the particular problems in their plants.

Means of Detecting Toxic Oxides Ready for Industrial Plants

The publication of a pamphlet describing the phenoldisulfonic acid method of detecting the toxic oxides of nitrogen which are a peril in some industrial plants has been announced by Dr. R. R. Sayers, director of the United States Bureau of Mines. This occupational hazard which is a potential drain on wartime man power exists in the

gaseous products of welding operations, in the exhaust of internal-combustion engines, in the vicinity of electrical discharges, in the combustion of nitrated materials, in the gases evolved in the use of explosives, and in the chemical processes involving nitration or the use of nitric acid.

The Bureau's report gives the details of this method's functioning as well as reviewing the work of others in the same field. The report entitled, *Determination of the Oxides of Nitrogen by the Phenoldisulfonic Acid Method* by R. L. Beatty, L. B. Berger, and H. H. Schrenk, may be obtained from the Bureau of Mines, Department of the Interior, Washington, D. C.

New Production Schedules for Aircraft Motors Planned

The scheduling of the production of fractional horsepower motors and their component parts to conform to aircraft production was proposed by the Fractional Horsepower Electric Motor Industry Advisory Committee meeting recently in Washington, D. C., with officials of the War Production Board and other government agencies. An attempt will be made to alleviate existing conditions whereby a 10- to 12-month backlog of orders is common among aircraft motor manufacturers. On the basis of information obtained from a survey in progress among these manufacturers, adjusted schedules aimed at making urgently needed motors available when needed and preventing motors from being built before they are actually required, will be prepared by the War Production Board.

Commutator production also is being scheduled to meet actual requirements. With the help of the copper division of the WPB, arrangements may be made to provide for short scheduling of copper for commutators when necessary.

Reports submitted at the meeting showed that \$23,500,000 worth of vital war products were delivered by the fractional-horsepower motor industry in January 1943.

Radio Helps Maintain Continuous Power Supply

On the home front, radio is playing a part in helping to maintain a steady flow of electric power to industries vital to the nation's war effort. Application of radio to the electric-power industry consists of a system of control whereby electric trouble is located automatically and prevented from spreading and shutting off power.

Radio sets in terms of the electrical industry are not to be confused with the type in the home. The set is connected to a high-voltage substation bus and instead of

having an antenna in the usual sense, is connected to the high-voltage transmission lines by means of special devices. The radio waves are guided or "carried" by the high-voltage conductor to which the set is connected. Hence the term carrier current, is applied to this particular application of radio. Usually all of this equipment is located out-of-doors, and is housed in weatherproof containers made of porcelain and steel.

In operation, one set is located at each terminal of a high-voltage transmission circuit. These bare conductors of electric power are exposed to sleet which sometimes causes the conductors to slap together, or to the dangers of lightning. Often as a result of damage during storms the transmission line no longer passes its electric power freely through its conductors. Large concentrations of power are stopped where the trouble has occurred and unless corrective measures are taken immediately, an entire power system may be short-circuited.

During the moment of short circuit, the radio plays its major role. Instantly every carrier-current radio set in the system is thrown into operation. In the sets closest to the trouble the protective relays trip the circuit breakers. This disconnects the short-circuited line and allows power to pass freely over the rest of the system. All radio sets on other lines, at the same time, prevent the other circuit breakers from being opened.

The entire protective system operates at high speed. The short circuit is located by the carrier-current radio within one-sixtieth of a second, and the entire trouble is cleared from the power system automatically in less than one-fifth of a second.

Limitation and Standardization

Save Materials and Man-Hours

By eliminating unnecessary frills in scores of articles from hairpins to industrial power trucks, the War Production Board in 1942 saved 600,000 tons of steel, 17,000 tons of copper, large quantities of other materials, and enough man-hours to build 23 Liberty ships, according to estimates recently made public.

The reductions in the use of materials and man-hours were accomplished through issuance of approximately 100 limitation orders. From February 1942, when the first simplification order was issued, through December 1942, 315 products were affected.

Limitation orders have reduced sizes or types of certain valves and fittings from 4,030 to 2,500, electric light bulbs from 3,500 to 1,700, heavy forged hand tools from 1,150 to 357, mechanical water coolers from 27 to 8, industrial power trucks from 221 to 50, X-ray equipment from 100 to 25, and fluorescent lighting fixtures from 200 to 2.

In addition to economies in the use of steel and copper, 82 simplification orders are estimated to have saved 180,000,000 yards of cloth, 30,000 tons of leather, 450,000,000 feet of lumber, 227,000 tons of oil of pulp, 35,000 tons of solder and 8,000

pounds of tungsten. The simplification orders have not only saved materials, but they also have increased production.

In addition to cutting out nonessential furbelows, the limitation orders have standardized many products. Simplification, it was pointed out, consists of the elimination of unnecessary parts of a given product. Standardization fixes the types in which it is produced.

It is in the production of weapons which are subject to the hazards of battle that standardization is most important, it was said. When standard components are made for tanks, guns, and airplanes, weapons needing spare parts can be reequipped more easily.

The work of standardization is carried forward in co-operation with professional engineering societies, the Armed Services, and the manufacturers. Where the Army and Navy use the same weapons, they have agreed in many instances to standardize their components. They have agreed to make common tests of battle worthiness. Co-operation between the Services and the WPB to standardize additional products is going forward in many fields. Standardization also has facilitated civilian production.

Roster of Scientific Personnel Helps Fill War Positions

Detailed information concerning the qualifications of more than 500,000 of the nation's scientists and professional men and women now has been catalogued by the National Roster of Scientific and Specialized Personnel (*EE, Feb., '43, p. 102*), and over 140,000 names have been certified to agencies engaged in the war effort, according to a report released by the National Resources Planning Board.

Through the Roster various war agencies have not only received the names of thousands of individuals for full-time positions, but they have also obtained the services of many scientific leaders to serve as consultants for short periods of time.

In co-operation with the Selective Service System, the Roster is continuing the task of completing the registration of all men from 18 to 65 years of age who have scientific or professional training or experience. Many of the most eminent scientists of America have collaborated in devising classification methods which can produce from a central register any desired combination of scientific skills within a few hours' time.

The central organization of the Roster was established jointly by the United States Civil Service Commission and the National Resources Planning Board in June 1940, as a precise index of the country's scientists and other specially qualified citizens. The job of developing and administering the Roster was placed in the hands of Leonard Carmichael, president of Tufts College, Tufts College, Mass., who was named director; and of James C. O'Brien, experienced Civil Service Commission executive, who was

appointed executive officer. The Roster now functions under the War Manpower Commission and is associated with its bureau of placement.

New Local Radio Service Made Available for Civilian Defense

The War Emergency Radio Service, two-way radio communication for use of civilian defense and other defense forces in local areas, has been made available jointly by the Office of Civilian Defense and the Federal Communications Commission.

The WERS has been assigned a number of frequencies by the FCC, the more important being from 112 to 116 megacycles. Three bands of several channels are planned: one to connect the local civilian-defense control center with the district control center; one to connect the local control center with local fixed points such as wardens' posts, fire houses, hospitals, public utilities, and industrial plants; and one to connect mobile forces like fire trucks and emergency medical teams with the control center. WERS transmitters use a maximum of 25 watts input power, which gives an effective communicating range to civilian-defense forces of approximately ten miles.

Local WERS's are set up by volunteer groups under specific authorization of FCC. Each person operating a WERS station must pass the elementary FCC test and obtain a permit from the FCC. Blanket licenses may be obtained from the FCC for all civilian-defense radio stations within one area of operation. Licenses are issued only to municipal or local governments and not to police departments, fire departments, or defense councils as such.

Reclamation Projects Power Output Increased

Power plants on Bureau of Reclamation projects in 11 western states produced in the calendar year 1942 more than 7,250,000,000 kilowatt-hours of electric energy, chiefly for war purposes, Secretary of the Interior Harold L. Ickes announced recently on the basis of a report from Commissioner John C. Page, excerpts of which follow.

"The 1942 output, speeded to meet the demands of war industries, showed an increase of 75 per cent, over the production in the calendar year 1941," Mr. Page reported.

"Substantial additions to capacity at the close of 1942 and early in 1943 now enable the plants on Bureau projects to operate at the rate of 9,000,000,000 kilowatt-hours annually. The annual rate will be increased to 10,000,000,000 kilowatt-hours by midsummer, which is more than the generation in the entire state of Illinois in 1940.

"Practically all of our increased output went into the reduction of aluminum and magnesium, the manufacture of airplanes, warships and merchant vessels, guns and

tanks, and into the processing of foodstuffs for the civilian population, the armed forces, and lend-lease.

"Large quantities of foodstuffs were produced on irrigated land watered by Bureau projects from reservoirs which also served hydroelectric power plants. While food production was limited by labor supplies in 1942, the output of critical crops showed substantial gains," the Commissioner added.

During 1943 additional installations cleared by the War Production Board at Reclamation plants will increase the total capacity to more than 2,000,000 kilowatts. These include two 75,000-kilowatt generators originally constructed for Shasta Dam of the Central Valley project in California which are being rushed into place at Grand Coulee Dam in order to meet additional load requirements in that area. Two more big 108,000-kilowatt generators are to go on the line at Grand Coulee during the year.

When the present schedule of installations is completed in the spring of 1944, the capacity on Reclamation projects will increase to 2,500,000 kilowatts, a volume greater than the total installed capacity of all electric plants in the 11 far western states at the close of the last war.

Television Commonplace After War, Says W. R. G. Baker

If only by training engineers in the art of high-frequency work so important in the present war, prewar television experimenting has justified itself, according to W. R. G. Baker (M '41), vice-president of the General Electric Company, Bridgeport, Conn., in an address to the Schenectady (N. Y.) Advertising Club on April 7, 1943.

Doctor Baker predicted a more important place for television in postwar civilian life than that it now occupies. War research, he pointed out, has broadened the usable high-frequency band to an extent never before available to television engineers.

Asserting that radio manufacturers now engaged in war production would have the means for mass production of television sets after the war, he stressed the necessity of setting up standards on the order of those adopted by the National Television Systems Committee, before large-scale production can be undertaken. As an example of the progress already made by radio manufacturers, Doctor Baker cited the change in the production of picture tubes. Before the war, picture tubes, which are an important element in pricing sets, could be imported more cheaply from Holland. Today United States manufacturers have the production advantage.

In Doctor Baker's opinion postwar television sets will produce pictures in black and white probably from 12 to 15 inches square which will allow the spectator to sit seven or eight feet away from his set and still enjoy the program. Any immediate adoption of color television would make obsolete existing transmitting equipment which must form the nucleus of future networks, he said. He stated that coaxial cables

or television relay stations or a combination of both will be used for relaying programs.

Revenue From Grand Coulee and Bonneville Dams Rising

A total of \$7,680,000 has been returned to the people of the United States during the past 12 months toward liquidation of their investment in Bonneville and Grand Coulee Dams and the 2,000-mile Federal transmission grid.

Bonneville Power Administrator Paul J. Raver, whose agency is required by law to dispose of Bonneville and Grand Coulee power, said this revenue was \$4,215,000 more than that collected from the sale of Columbia River power in the year 1941.

It was \$2,518,000 more than collections for the 12 months ending June 30, 1942, the Federal Government's fiscal year. By New Year's day the Bonneville Administration collected a total of \$12,476,000 from its three-year power sales since it first began deliveries late in 1939.

Summarizing the year's business, Administrator Raver said that on the basis of present contracts and commitments, Bonneville's annual power sales will be at the rate of between 12 and 14 million dollars by next June. By the end of calendar year 1944, the rate will have jumped to about \$18,000,000 annually.

Bureau of Mines Reports on Monazite

Publication of a detailed report on the sources, uses, and mining of monazite sand employed principally in the manufacture of arc-lamp electrodes, pyrophoric alloys, mildew proofing, and ceramics has been announced by R. R. Sayers, director of the United States Bureau of Mines.

All monazite deposits worth developing commercially now are located outside the United States. Brazil has assumed the role of chief supplier formerly played by India and, before 1909, by the United States. Small deposits which are not economically valuable still exist in the sand dunes of North and South Carolina, Florida, and Idaho.

Thorium and the rare-earth elements cerium, praseodymium, neodymium, and lanthanum are present in the sand. Thorium is used in electron emissive elements, in radio-tube and tungsten-lamp filaments, gas mantles, high-temperature refractories, X-ray targets, and as a catalyst. Copies of the report, Information Circular 7233, may be obtained from the Bureau of Mines, Department of the Interior, Washington, D. C.

Foreign Patent Libraries Organized. The opening of libraries of copies of patents vested from enemy and other aliens, which may be used by American manufacturers, has been announced by Alien Property

Custodian, Leo T. Crowley. The libraries are situated at 120 Broadway, New York, N. Y., and at the Field Building, Chicago, Ill. Vested applications will be made ready for inspection as rapidly as they become available. Those interested may obtain information on ordering copies and on securing licenses to use the patents at the libraries.

EDUCATION . . .

New York State Changes License Requirements for Engineers

Engineers intending to practice in New York state may now take part of their qualifying examination as soon as they earn their engineering degrees, instead of waiting four years as was previously necessary. Acting on proposals of professional engineering groups, the Board of Regents has amended the regulations of the New York Commissioner of Education.

Under the new regulations the graduate engineer may take a preliminary examination on theory upon receiving his degree from a registered college of engineering and four years later a final one based on engineering experience. The preliminary examination confers the status of engineer-in-training for ten years. After that the applicant may be required to repeat the first section before taking the second part of the examination. Applications for the first examination under the new system, which will be held in June 1943, must be filed not later than May 1, 1943. A candidate must be 21 years old. The State Department of Education may substitute satisfactory practical experience for the engineering educational requirements.

Iowa Reopens Management Course. Lectures and round-table sessions conducted by practicing managers and industrial engineers will be a special feature of the fifth annual three-week summer course in management offered by the University of Iowa from June 7 to 25, 1943. Factory training programs will be given primary emphasis in an effort to serve those working to increase war production. Plant layout, motion and time study, wage incentives, and waste elimination also will be studied. Ralph M. Barnes, professor of industrial engineering, is in charge of the course.

Handbook on Education and the War Published

Publication of a comprehensive "Handbook on Education and the War" was announced recently by the United States Office of Education. Based on the proceedings of the National Institute on Education and the War, the Handbook is an over-all survey of the major wartime problems of education.

The book containing 359 pages is di-

vided in two parts, one containing the full text of statements by heads of those Federal war agencies which touch education, and the other part containing reports of symposiums held on 26 of the most acute wartime educational issues. The 26 key problems are grouped under 4 general headings: Training Manpower, School Volunteer War Service, Curriculum in Wartime, and Financing Education in Wartime.

Copies of the book are available from the Superintendent of Documents, Washington, D. C., at 55 cents each.

OTHER SOCIETIES.

Dushman Speaks at Installation of Brooklyn Sigma Xi Chapter

"It is incumbent on scientists to think more clearly about their role in the utilization of their work and about the manner in which they may help toward evolving a better world," declared Saul Dushman (A '13), assistant director of the General Electric Research Laboratory, at the recent installation of a new chapter of Sigma Xi recently in the Polytechnic Institute of Brooklyn.

Dissenting with the view that the scientific method can be of no help in the field of social problems, Doctor Dushman pointed out that there are already institutions for scientific investigations in economics and sociology and stated "A great purpose which such institutions might serve would be that of training men to become legislators and administrators of public office, men who will become expert in national or international problems and who will therefore be able to give the nation the best advice possible."

Fifth Volume of Engineering Reports Issued

The fifth in a series of volumes of engineering reports dealing with the technical problems of inductive and structural co-ordination of power and telephone systems was published recently by the joint subcommittee on development and research of the Edison Electric Institute and the Bell Telephone System.

This latest volume contains 11 reports (39 to 49 inclusive). In four reports devoted to noise induction, the subjects discussed are the inductive co-ordination of rural power and telephone systems, the wave shape of multiphase power rectifiers, the susceptiveness of telephone subscriber sets, and frequency weighting for telephone message circuit noise. Five reports concerned primarily with low-frequency induction deal with the characteristics of power system faults to ground, the inductive co-ordination aspects of grounding power system neutrals through Petersen coils, low-frequency shielding in telephone cables, short-circuiting relay protectors, and neutralizing transformers. A report on the

Future Meetings of Other Societies

American Chemical Society. September 6-10, 1943, Minneapolis, Minn.

American Institute of Mining and Metallurgical Engineers. Spring meeting, petroleum division, May 6-8, 1943, Dallas, Tex.; joint fuels conference, October 28-29, 1943, Pittsburgh, Pa.

American Society for Metals. Annual convention, October 18-22, 1943, Chicago, Ill.

American Society of Heating and Ventilating Engineers. Semiannual meeting, June 6-7, 1943, Pittsburgh, Pa.

American Society of Mechanical Engineers. Semiannual meeting, June 14-16, 1943, Los Angeles, Calif.

American Society for Testing Materials. Annual meeting, June 28-July 2, 1943, Pittsburgh, Pa.

American Society of Refrigerating Engineers. 30th spring meeting, June 1-3, 1943, Cleveland, Ohio.

Association of Iron and Steel Engineers. Spring conference, May 10, 1943, Pittsburgh, Pa.

Canadian Electrical Association. Annual meeting, June 17-18, 1943, Quebec, Que.

Edison Electric Institute. Electrical equipment committee, prime movers committee, transmission and distribution committee, accident prevention committee, meetings, May 10-13, 1943, Chicago, Ill.

Illuminating Engineering Society. Great Lakes regional conference, June 5, 1943, Detroit, Mich.

National Fire Protection Association. May 10-14, 1943, Chicago, Ill.

Society for the Promotion of Engineering Education. Annual meeting, June 18-20, 1943, Chicago, Ill.

Society of Automotive Engineers. National transportation and maintenance meeting, May 5-6, 1943, New York, N. Y.; Diesel engine, fuels, and lubricants meeting, June 2-3, 1943, Cleveland, Ohio.

Society of Naval Architects and Marine Engineers. Spring meeting, May 27-28, 1943, Bath and Portland, Maine.

positive disconnection of distribution circuits during faults to ground bears chiefly on structural co-ordination questions. The remaining report on the bonding of aerial telephone cable sheaths to multigrounded power neutral wires is concerned with all three fields—noise-frequency and low-frequency inductive co-ordination, and structural co-ordination—and also with certain electrolysis questions. Much of the information in the volume has immediate application to problems which have arisen in connection with the war effort.

As the earlier volumes in this series, these reports present primarily the results of investigations undertaken to provide methods of co-ordinating power and communication systems. However, in many cases, the underlying data contain elements of value in power system operating and design problems, and the analyses and discussions as presented in the reports are sufficiently comprehensive to set forth this information in usable form.

JOINT ACTIVITIES

Two New War Standards Issued

A "War Standard for Protective Lighting of Industrial Properties" and an

"American War Standard for Electrical Indicating Instruments" have recently been completed by the American Standards Association. The lighting standard seeks to decrease the danger of theft and sabotage in war plants. Specific treatment is given to plants with fenced boundaries, water front boundaries, pedestrian and conveyance entrances, open yards, outdoor storage spaces, and piers and docks. Since the minimum degree of lighting recommended is greater than that allowed in dim-out areas, plant managements are referred to the appropriate government officials before installing protective lighting systems.

The second standard aiming at obtaining interchangeability of small panel type instruments of all manufacturers, is expected to ease a problem of supply confronting the armed forces for which these instruments are necessary equipment. Performance specifications under the extremes of temperature, humidity, vibration, and shock encountered in military action, except that of direct mounting on aircraft instrument panels, are included.

ECPD Publishes Annual Report

Approved engineering curricula at 131 educational institutions are listed in the recently issued tenth annual report of the Engineers' Council for Professional Development, a joint conference of the professional societies of the civil, mechanical, electrical, mining and metallurgical, and chemical engineers, the engineering educators, and the Engineering Institute of Canada. The curricula listed are those inspected by the committee on engineering schools to October 18, 1942. Courses in aeronautical and industrial engineering are approved options to some of the older courses on the list which was compiled before the Army and Navy training programs took effect. Although regular courses of study which have been accelerated for wartime are included, the list does not apply to short intensive programs offered to meet special war programs.

The report contains Council Chairman R. E. Doherty's (F '39) review of the year's activities as well as reports from all the council's committees and representatives of its constituent organizations. The preparation of a manual for junior engineers and a proposal for a written ethical code for engineers are announced.

Copies of the report may be obtained from the secretary of ECPD, 29 West 39th Street, New York, N. Y., for 25 cents each.

ASA Electrical Committees Report on Year's Activities

War needs have had a noticeable effect on the activities of the American Standards Association sectional committees on electrical projects in recent reports on the year's activities of these committees. Many committees have postponed their regular work or have concentrated their efforts on emergency revisions to meet wartime needs. Despite this wartime activity,

19 regular standards were approved by the ASA during the past year on recommendation of the Electrical Standards Committee, ASA co-ordinating committee for electrical standards.

Co-operation between Canada and the United States on electrical problems was furthered during the past year by an invitation from the Canadian Engineering Standards Association that the ASA appoint a corresponding member on standards committees working on the Canadian Electrical Code. The Electrical Standards Committee has recommended that Victor H. Tousley, secretary of the ASA committee on the National Electrical Code and electrical field secretary of the National Fire Protection Association, be appointed corresponding member of the committee on the Canadian Electrical Code, Part I and that A. B. Smith, of the National Electrical Manufacturers Association, be named as corresponding member for Part II of the Canadian Electrical Code. In taking this action the ESC expressed "the great appreciation of the ASA and the electrical industry in the United States for this concrete expression of the close harmony between industry in the two countries." The ESC recommended that the ASA invite the Canadian Engineering Standards Association to appoint corresponding members on the committees in charge of the National Electrical Code (ASA C1). It called attention, however, to the fact that the ASA has no committee similar to the one in charge of Part II of the Canadian Electrical Code, which covers standards for electrical wiring and devices. This work under the ASA is handled by the proprietary sponsorship method through project C33, which at present is inactive.

New ASA Directors. Four new members have been elected to the Board of Directors of the American Standards Association for three-year terms beginning January 1, 1943. The directors are: J. T. Barron (F'27), vice-president, Public Service Electric and

Testing Radio Under Stratospheric Conditions

Aircraft and electronic equipment is being checked in the bomber-nose test chamber shown in the picture under the stratospheric conditions encountered in high-altitude flying. Developed by the RCA Victor division of Radio Corporation of America, two such test chambers are now in operation at the Camden plant. An actual unfinished nose of a famous American bombing plane, the chamber is made of Plexiglas, a transparent plastic, and it permits the complete testing and



inspection of any piece of radio apparatus by several engineers at the same time

Gas Company, Newark, N. J., C. A. Gill, vice-president, Reading Company, Philadelphia, Pa., R. G. Griswold, president, Electric Advisers, Inc., New York, N. Y., and Alvah Small (M'37), president, Underwriters Laboratories, Inc., Chicago, Ill. They were nominated, respectively, by the AIEE, the Association of American Railroads, the American Gas Association, and the National Safety Council.

electrical degrees. Coil 1 differs from coil 8 by $7 \times 50 = 350$ degrees, which is, of course, also 10 degrees. Likewise, coil 15 is 10 degrees from coil 8 and 20 degrees from coil 1. Continuing in this way, we select coils 1, 8, 15, 22, 29, and 36, each differing by 10 degrees from the next one. Since the number of poles and the number of slots can both be divided by 4, if we add 18, 36, or 54 to each of the above numbers, we shall get three more sets of coils, all in phase or directly opposed to one another, in all 24 coils or $\frac{1}{3}$ of the total.

As far as the electromotive force is concerned, we could connect these in any order we wished, but for convenience, it is better to select coils close to one another. For example, we might select for one phase:

72- 1- 4- 8-11-15	Group 1
18-19-22-26-29-33	Group 2
36-37-40-44-47-51	Group 3
54-55-58-62-65-69	Group 4

These four groups may be connected in series or parallel as desired. To find the coils of the other two phases, we merely need to add 12 and 24 to each of the above numbers.

Since each group consists of six coils whose emfs differ by 10 degrees, the distribution factor is:

$$\frac{2 \cos 5^\circ + 2 \cos 15^\circ + 2 \cos 25^\circ}{6} = 0.956$$

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are

expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Common Error in the Distribution Factor

To the Editor:

The article, "A Common Error in the Distribution Factor of Electrical Machines," by Rienk Andriessen, published in the February 1943 issue of *Electrical Engineering*, pages 68-72, makes a very simple matter seem complicated. In the

first place, any correctly connected three-phase winding must have a distribution factor not greater than unity and not less than $3 \div \pi = 0.955$. The factor of unity applies only to the rare case of one coil per phase per pole. Actually, the constant is almost always between 0.966 and 0.955.

The case discussed is that of a 20-pole machine with 72 coils. Each coil differs from the next one by $10 \times 360 \div 72 = 50$

It should be noted also that full pitch coils are impossible with a fractional slot winding. Probably in the above case each coil would span three slots, giving an angle between coil sides of $3 \times 50 = 150$ degrees. The pitch factor would then be $\cos 150/2 = 0.966$ and the complete winding factor would be $0.956 \times 0.966 = 0.924$.

BENJAMIN F. BAILEY (A '07, F '21)

(Head of electrical engineering department, University of Michigan, Ann Arbor)

Current-Transformer Excitation Under Transient Conditions

To the Editor:

In view of the increasing importance of the paper, "Current Transformer Excitation Under Transient Conditions," by D. E. Marshall and P. O. Langguth, published in *AIEE Transactions*, volume 48, 1929, pages 1464-74, I submit for your consideration the following comments:

Equation 15 on page 1468 contains a misprint. The first term on the right-hand

side of the equation which reads $R_2 T_1 \epsilon^{\frac{-t}{T_1}}$ should read $\frac{1}{R_2 T_1} \epsilon^{\frac{-t}{T_1}}$

This term is derived from the term

$$\frac{1}{L_1 + L_2} \epsilon^{\frac{-R_2 t}{L_1 + L_2}} \text{ in equation 13}$$

To simplify, $\frac{R_2}{L_1 + L_2}$ is called $\frac{1}{T_1}$ in equation 14. From equation 14,

$$L_1 + L_2 = R_2 T_1$$

and

$$\frac{1}{L_1 + L_2} = \frac{1}{R_2 T_1}$$

So that

$$\frac{1}{L_1 + L_2} \epsilon^{\frac{-R_2 t}{L_1 + L_2}} \text{ of equation 13}$$

becomes

$$\frac{1}{R_2 T_1} \epsilon^{\frac{-t}{T_1}} \text{ in equation 15}$$

My reason for mentioning this is that if a student of the article does not happen to check this substitution, on account of its simplicity, and goes on to take equation 15 for granted, when he substitutes for i to arrive at equation 16, his solution will be complicated by the presence of $R_2 T_1$ in the numerator instead of in the denominator, and he will be unable to arrive at the solution given by the authors in equation 16, which of course, is derived correctly from equation 13.

The next point concerns equation 18 on page 1469. It appears to me that the last

term of the equation given as $+\frac{\epsilon^{\frac{-t}{T_1}}}{1 + \omega^2 T_1^2}$ should read minus instead of plus.

To illustrate my point, it will be necessary to deduce equation 18 from equation 16 on page 1468.

Equation 16 reads

$$i_1 = I \left\{ \frac{\sqrt{R_2^2 + \omega^2 L_2^2}}{R_2 \sqrt{1 + \omega^2 T_1^2}} \left[\sin(\omega t + \alpha + \phi - \Delta) - \sin(\alpha + \phi - \Delta) \epsilon^{\frac{-t}{T_1}} \right] + \right.$$

$$\left. \frac{L_2 - R_2 T}{R_2(T - T_1)} \sin \alpha \left(\epsilon^{\frac{-t}{T}} - \epsilon^{\frac{-t}{T_1}} \right) \right\}$$

$$\text{where } T_1 = \frac{L_1 + L_2}{R_2}; \tan \phi = \frac{\omega L_2}{R_2}; \tan \Delta = \omega T_1$$

The assumption is then made that $L_2 = 0$, and the value of $\sin \alpha$ is taken as that which causes the maximum primary transient, that is, $\sin \alpha = 1$.

On making these substitutions to arrive at equation 18

$$\phi = \tan^{-1} \frac{\omega L_2}{R_2} = \tan^{-1} 0 = 0$$

Therefore ϕ disappears.

Now take the sine term

$$\sin(\omega t + \alpha - \Delta)$$

Expand as

$$\sin[\alpha + (\omega t - \Delta)]$$

$$= \sin \alpha \cos(\omega t - \Delta) + \cos \alpha \sin(\omega t - \Delta)$$

But

$$\sin \alpha = 1$$

therefore

$$\cos \alpha = 0$$

$$\text{Expansion} = \cos(\omega t - \Delta)$$

$$= \cos(\omega t - \tan^{-1} \omega T_1)$$

Now take

$$\sin(\alpha - \Delta)$$

$$\text{Expanding} = \sin \alpha \cos \Delta - \cos \alpha \sin \Delta$$

$$= \cos \Delta$$

$$= \cos \tan^{-1} \omega T_1$$

$$= \cos \tan^{-1} \frac{\omega T_1}{1}$$

The cosine of the angle whose tangent is $\frac{\omega T_1}{1}$ is

$$\frac{1}{\sqrt{1 + \omega^2 T_1^2}}$$

Substituting in equation 16

$$i_1 = I \left\{ \frac{\sqrt{R_2^2}}{R_2 \sqrt{1 + \omega^2 T_1^2}} \left[\cos(\omega t - \Delta) - \right. \right.$$

$$\left. \left(\frac{1}{\sqrt{1 + \omega^2 T_1^2}} \right) \epsilon^{\frac{-t}{T_1}} \right] -$$

$$\left. \frac{R_2 T}{R_2(T - T_1)} \left(\epsilon^{\frac{-t}{T}} - \epsilon^{\frac{-t}{T_1}} \right) \right\}$$

$$i_1 = I \left[\frac{1}{\sqrt{1 + \omega^2 T_1^2}} \cos(\omega t - \tan^{-1} \omega T_1) - \right.$$

$$\left. \frac{T}{T - T_1} \left(\epsilon^{\frac{-t}{T}} - \epsilon^{\frac{-t}{T_1}} \right) - \frac{\epsilon^{\frac{-t}{T_1}}}{1 + \omega^2 T_1^2} \right]$$

which agrees precisely with equation 18 of the article, except for the sign of the last term.

The last point is that it appears that a minus sign has been omitted between the two terms in equation 20 on page 1469.

Equation 20, given in the article as

$$U_{\max} = A \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{-T_1}{T_1-T}} \times (A+B) \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{-T}{T_1-T}}$$

is derived from having substituted the value for t

$$t = \log_{\epsilon} \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{TT_1}{T_1-T}} \text{ equation 19}$$

in the equation

$$\mu = A \epsilon^{\frac{-t}{T}} - (A+B) \epsilon^{\frac{-t}{T_1}} \text{ equation 17}$$

It may be noted that t is the time at which the transient term reaches its maximum value. If this substitution is performed in equation 17, we have

$$U_{\max} = A \epsilon^{-\frac{1}{T} \log_{\epsilon} \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{TT_1}{T_1-T}}} - (A+B) \epsilon^{-\frac{1}{T_1} \log_{\epsilon} \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{TT_1}{T_1-T}}}$$

Since

$$n \log_{\epsilon} x = \log_{\epsilon} x^n$$

$$U_{\max} = A \epsilon^{\log_{\epsilon} \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{-T_1}{T_1-T}}} - (A+B) \epsilon^{\log_{\epsilon} \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{-T}{T_1-T}}}$$

Simplifying further:

$$\text{If } y = \epsilon^{\log_{\epsilon} x}$$

$$\log_{\epsilon} y = \log_{\epsilon} \epsilon x \log_{\epsilon} \epsilon$$

$$y = x$$

$$\epsilon^{\log_{\epsilon} x} = x$$

Therefore

$$U_{\max} = A \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{-T_1}{T_1-T}} - (A+B) \left[\frac{T_1}{T} \frac{A}{A+B} \right]^{\frac{-T}{T_1-T}}$$

which agrees with the equation 20 in the article, except that the minus sign has been added. Because this article appears first on any list of references dealing with the subject of the saturation of current transformers by transient magnetizing current and the effect of this saturation on differential relay protection, it occurred to the

writer that the mention of these discrepancies would prove of interest.

G. D. ETCHES

(Mechanical engineering department, Consolidated Edison Company of New York, Inc., N. Y.)

Cooling Error in Transformer-Temperature Measurement

To the Editor:

The letter, "Cooling Error in Transformer-Temperature Measurement," by Frederick Bauer and Jerome J. Taylor published in the March 1943 issue of *Electrical Engineering*, page 138, illustrates the need for the exercise of good judgment when making decisions as to what factors to neglect in order to simplify tests. Ordinarily we are used to thinking of electrical and magnetic transients as being essentially fast, while thermal transients are usually considered as being very slow, and offhand it would not appear that one could appreciably affect the other; in these particular cases, however, a thermal transient can affect the performance of an inductive circuit to a considerable degree.

It would seem that the practice of short-circuiting other windings of a transformer when making resistance measurements would reduce the error under discussion,

although it is recognized that this cannot completely eliminate the error, since any winding must possess some resistance and so cannot entirely prevent, but only retard, changes in magnetic flux. For this reason it might be desirable, in questionable cases, actually to determine the induced voltage at the instant of making a resistance measurement, by placing either a voltmeter, millivoltmeter, or potentiometer across an open winding (taking proper precautions against accidental voltage surges). The induced voltage in the winding under test could be computed from turn ratio, and then by subtraction from the indicated voltage, the true IR drop could be obtained.

In making measurements of resistances of highly inductive circuits, the length of time for the induced voltage to become negligible is not always appreciated; this is especially true when using a bridge. In some cases minutes are required before an accurate determination can be assured, and, since the rate of change of apparent resistance becomes almost imperceptible, erroneous balances are sometimes made. It would be very desirable to establish some simple criterion or rule of procedure which would definitely eliminate this uncertainty.

C. T. HESSELMAYER (M'42)

(Electrical test engineer, Chicago (Ill.) District Electric Generating Corporation)

simply and briefly the principal facts relating to the ignition of inflammable gas mixtures by sparks, flames, incandescent solid particles, and other localized sources. Certain theories which have been put forward to co-ordinate or explain the action of these sources are also described. The book is intended primarily for engineers concerned with internal-combustion engines and with the prevention of explosions in mines and factories.

Plastics Catalog 1943, an Encyclopedia of the Plastics Industries. Plastics Catalogue Corporation, New York, N. Y., Chicago, Ill., 864 pages, illustrations, etc., 12 1/2 by 9 inches, fabrikoid, \$5. (ESL).

A combination of technical encyclopedia and trade directory, this volume contains authoritative articles on properties of the various plastics, on plasticizers and solvents, on manufacture, machinery, molding, fabricating, laminates, coatings, synthetic fiber, and synthetic rubber. The directory section covers the manufacturers of plant equipment, and includes a bibliography, a glossary, an index of molders' marks and a complete list of makers.

Audel's New Radioman's Guide, Theory, Construction and Servicing, Television. By E. P. Anderson. Theodore Audel and Company, New York, 1942. 756 pages, illustrations, etc., 6 1/2 by 5 inches, fabrikoid, \$4. (ESL).

The fundamental principles of electricity, radio, and sound are first discussed. The equipment used in radio practice is described and present circuit diagrams for many different types of receivers, as well as examples of sample calculations for radio work are presented. The book includes special chapters dealing with the automatic alarm, the radio compass, and marine and aircraft communications.

History of Science and Its Relations with Philosophy and Religion. By Sir W. C. Dampier. 3d edition. Macmillan Company, New York, N. Y.; University Press, Cambridge, England, 1942. 574 pages, diagrams, etc., 9 1/2 by 6 inches, cloth \$2.95. (ESL).

In the interval since the previous publication of this work, much new information has been obtained, which called for extensive changes. A new chapter, covering the period 1930 to 1940, has also been added. The book aims to present an account of the development of scientific knowledge from ancient times to the present day.

Fundamentals of Electric Waves. By H. H. Skilling. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1942. 186 pages, diagrams, etc., 9 by 6 inches, cloth, \$2.75. (ESL).

In this introductory study of electric waves, the principles of wave action and, in particular, the basic ideas of Maxwell's equations are presented in a way that has proved to be understandable to students. These ideas are discussed and used in simple examples in order to increase the

NEW BOOKS . . .

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Radio Today, the Present State of Broadcasting. (Geneva studies, volume 12, number 6, July, 1942). By A. Huth. Geneva Research Centre, Graduate Institute of International Studies, 132 rue de Lausanne, Geneva, Switzerland, 1942. 160 pages, tables, 8 1/2 by 5 1/2 inches, paper, 40 cents. (ESL).

The organization and financing of broadcasting, the method of transmission, the programs offered, and the number of listeners are discussed. Broadcasting available throughout the world and a brief account of recent developments are given also. The study is intended to provide a survey of the whole field with emphasis upon its permanent problems and the solutions that have been devised.

The Radio Amateur's Handbook (20th edition). American Radio Relay League, West Hartford, Conn., 1943. 478 pages, illustrations, etc., 9 1/2 by 6 1/2 inches, paper,

\$1 in the United States; \$1.50 elsewhere; \$2.50, bound. (ESL).

The new edition of his well-known manual of high-frequency radio communication follows the model of earlier ones, but has been revised and expanded to meet current conditions. A chapter on the war emergency radio service has been added. The book is intended to provide a simple nonmathematical text on the theory, design, and operation of radio-communication equipment with full information on the construction of apparatus.

Electrical Instruments (course 12). Industrial Relations Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., 1942. 165 pages, 8 1/2 by 11, \$2.50.

The objective of this course is to describe electric measuring instruments in a way that will produce the maximum amount of variability and originality in their use. It is intended to give a general description of practical application of the instruments the modern engineer has at his command. There are chapters on instruments of similar motivation, instruments of similar purpose, factors to be measured, construction features, selection and use, and maintenance and repair.

Principles of Ignition. By J. D. Morgan. Sir Isaac Pitman and Sons, London, England, 1942. 133 pages, diagrams, etc., 9 by 5 1/2 inches, cloth. (ESL).

The purpose of this book is to describe

students' familiarity with them. Physical concepts are stressed without neglecting mathematical exactness or the requirements of engineering practice.

Audel's Electrical Power Calculations. By E. P. Anderson. Theodore Audel and Company, New York, N. Y., 1941. 421 pages, illustrations, etc., $6\frac{1}{2}$ by 5 inches, fabrikoid, \$2. (ESL).

This is a collection of practical electrical problems and their solutions. It puts special emphasis on the fundamental laws of electricity and includes the necessary mathematical formulas. Complete solutions are given for 275 electrical problems selected from the average practice of electrical men. The book is divided into two parts: direct current and alternating current, and includes the subjects of power transmission and radio circuits.

Principles of Aeronautical Radio Engineering. By P. C. Sandretto. McGraw-Hill Book Company, New York, N. Y., and London, England, 1942. 414 pages, illustrations, etc., $9\frac{1}{2}$ by 6 inches, cloth, \$3.50. (ESL).

An engineering treatment is given of the peculiar problems that are involved in the use of radio in air transportation and of the means taken to solve them. The nine radio facilities used in modern air-transport practice are considered in detail. The book is written chiefly from the point of view of commercial airline operation and assumes some preliminary knowledge of radio.

Welding. By J. A. Moyer. McGraw-Hill Book Company, New York, N. Y., and London, England, 1942. 185 pages, illustrations, etc., 9 by 6 inches, cloth, \$2.25. (ESL).

The major part of this textbook is devoted to oxyacetylene and arc-welding methods, especially applied to iron and steel. The apparatus and technique are described in a general way, with information on the metallurgy of welds, test methods, and costs. A chapter on metal cutting is included, and other methods of welding (resistance, atomic-hydrogen, thermite) are described briefly.

Communication Circuits. By L. A. Ware, H. R. Reed. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1942. 287 pages, diagrams, etc., $9\frac{1}{2}$ by 6 inches, cloth, \$3.50. (ESL).

The theory of communication circuits is presented as a first course in communication engineering for those training for civilian duties or for service in the armed forces. The basic principles of communication lines and their associated networks are presented, covering the frequency range from voice frequencies through ultrahigh frequencies. Special attention is given to ultrahigh-frequency transmission.

Federal Power Commission and State Utility Regulation. By R. D. Baum. American Council on Public Affairs, Washington, D. C., 1942. 301 pages,

9 by 6 inches, paper, \$3; cloth, \$3.75. (ESL).

This is a study of the relations of the states with the Federal Power Commission. The disputes as to jurisdiction that have arisen, the experience of the Commission in controlling water power, accounting, and rates, and the efforts for collaboration are discussed. There is a bibliography.

Transients in Linear Systems, Studied by the Laplace Transformation, volume 1. Lumped-Constant Systems. By M. F. Gardner, J. L. Barnes. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1942. 389 pages, diagrams, etc., $9\frac{1}{2}$ by 6 inches, cloth \$5. (ESL).

This exposition of the subject is intended primarily for graduate students of electrical and mechanical engineering, but can be used also for graduate work in mathematical physics and applied mathematics. An extensive bibliography is included.

Elementary Mathematics. By H. Levy. Ronald Press Company, New York, N. Y., 1942. 216 pages, illustrations, 8 by 5 inches, cloth, \$1.50. (ESL).

This is a British text intended primarily to assist students of aeronautics in obtaining a solid foundation for further study. The explanations are clear and simple, and the range covered is a wide one, extending from whole numbers and fractions to the use of vectors, functions, and so forth. Students of science generally will find the book helpful.

Army Engineers in Review. By B. W. Leyson. E. P. Dutton and Company, New York, N. Y. 1943. 202 pages, illustrations, etc., $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, cloth, \$2.50 (ESL).

This book describes the work of the Corps of Engineers of the United States Army in peace and in war. It also gives something of its history and tells how it is organized and trained. Young men interested in joining the Corps will find information on the training required and the fields of work.

A-C Calculation Charts. By R. Lorenzen, John F. Rider, Inc., New York, N. Y., 1942. 165 pages, illustrations, $9\frac{1}{2}$ by $12\frac{1}{3}$, \$7.50.

This book contains 146 charts designed to facilitate a-c calculations in series circuits, parallel circuits, series-parallel, and mesh circuits, at frequencies of 10 cycles to 1,000 megacycles. It is intended to save time for engineers and others working on electrical communication and power problems.

Essential Mathematics for Skilled Workers. By H. M. Keal, C. J. Leonard. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1942. 293 pages, illustrations, etc., $7\frac{1}{2}$ by 5 inches, cloth, \$2. (ESL).

Provides a concise review covering the computations used by workers in applied science. Intended for shop workers, stu-

dents without college training, and those wishing a practical reference book.

Guide to Cathode Ray Patterns. By M. Bly. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 39 pages, diagrams, paper, loose-leaf binder, \$1.50. (ESL).

This collection of cathode-ray patterns summarizes in convenient form the types encountered in the usual course of laboratory and test-bench work. Over one hundred forms are shown.

Principles of Electronics. By R. G. Kloeffler. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1942. 175 pages, illustrations, etc., $9\frac{1}{2}$ by 6 inches, cloth, \$2.50. (ESL).

A short introductory book on electronics, intended for sophomore or junior students of electrical engineering, and to be followed by a mathematical treatment of the subject.

PAMPHLETS . . .

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Apprentice Training for America's Youth. War Manpower Commission, Apprentice-Training Service, Washington, D. C., 1942. 6 pages, no charge.

The National Apprenticeship Program. War Manpower Commission, Apprentice-Training Service, Washington, D. C., 1942. 8 pages, no charge.

Plant Protection Fact Sheet. Editorial Section, Office of Civilian Defense, Washington, D. C., 1943. 7 pages.

Index to ASTM Standards. American Society for Testing Materials, 260 Broad Street, Philadelphia, Pa., 1942. 225 pages, no charge.

Wartime Activities. Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago, Ill., 1943.

CMP, How Materials and Production Controls Work. Research Institute of America, 292 Madison Avenue, New York, N. Y., 1943. 100 pages, \$2.

Questions and Answers Regarding Operation under the Controlled Materials Plan. United States Government Printing Office, Washington, D. C., 1943. 5 pages.

Road Tests of Automobiles Using Alcohol-Gasoline Fuels. By R. G. Paustian. The Iowa State College *Bulletin*, Ames, 1942. 56 pages.

Industrial Fire Brigades Training Manual. National Fire Protection Association, 60 Batterymarch Street, Boston, Mass., 1943. 173 pages, \$1.50.